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RADIO: BEAM AND BROADCAST

TO THE INVENTORS OF

RADIO-TELEGRAPHY AND RADIO-TELEPHONY

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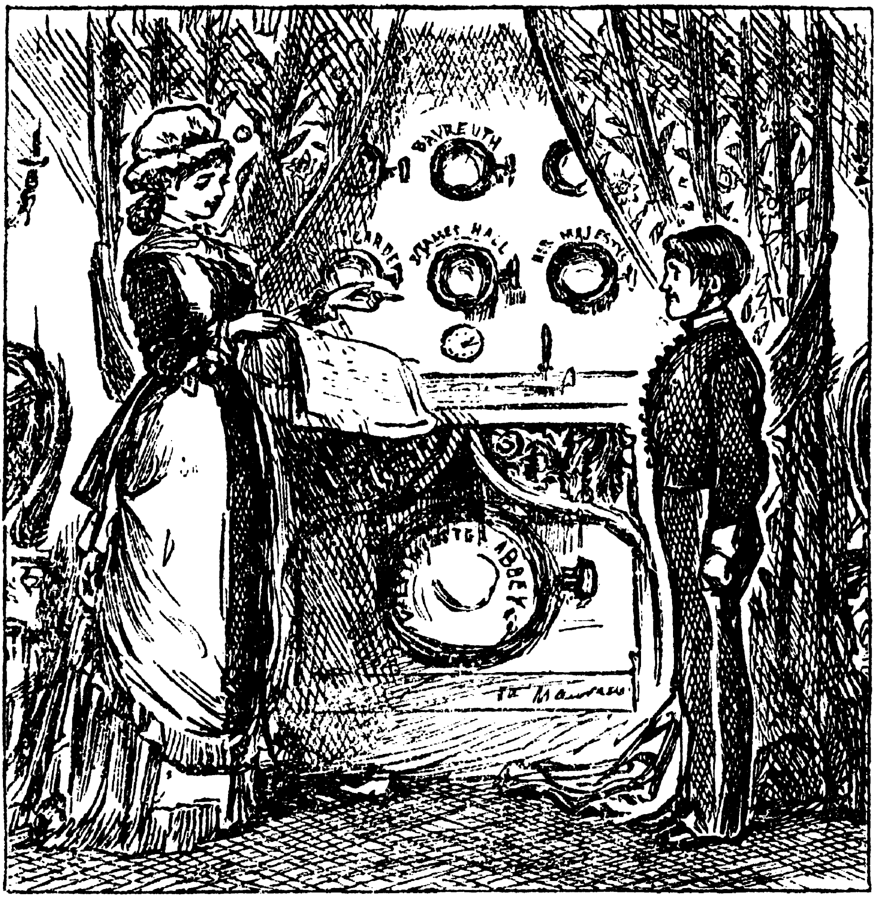

Musical Mistress of House ("on hospitable thoughts intent"). "Now, recollect, Robert, at a Quarter to Nine turn on 'Voi che Sapete' from Covent Garden; at Ten let in the Stringed Quartette from St. James's Hall; and at Eleven turn the last Quartette from 'Rigoletto' full on. But mind you Close one Tap before Opening the other!" *Buttons.* "Yes, Mum!"

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RADIO: BEAM AND BROADCAST

ITS STORY AND PATENTS

By A. H. MORSE

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INTRODUCTION

The term " Radio " is used herein to connote radio-telegraphy and radio-telephony, and not merely broadcasting.

The bibliography of radio is already very extensive, and while it contains much of a trashy or partisan order, the balance very well covers the technical aspects of the subject to date. There should, however, be room for a book which presents the subject in a novel or more lucid way, or for one that considers it from a new point of view; and it is in the latter class that it is hoped that this book will find a place.

Within the last few years the radio field has been invaded by many thousands of persons who know nothing of its evolution, and are therefore sometimes unable to distinguish between what is new and what is old. The consequence is that they waste much time and money in re-inventing old devices, and in evolving others to circumvent imagined patents on inventions long since in the public domain. The case of the spider-web coil may be cited as an example. This will be found to have been illustrated and described several years before the Great War (12), but was heralded as a novelty two or three years ago. It is one of the author's objects to help to correct the perspective of these newcomers; and it is hoped that this book will be of some assistance also to British and American Patent Agents and Attorneys (new to the art), Inventors, Experimenters, Journalists, Radio enthusiasts, and " Whymen " generally, on both sides of the Atlantic.

The evolution of the radio art is traced herein, mainly through the patent office records of inventions in use to-day, or their lineal forebears. As a consequence, many

inventions of great merit and one-time promise receive little or no mention; and, except in a few cases, where inventions are cited merely as evidence of the contemporary knowledge of the art, the selection has been made, not by the author, but by the test of utility. It may be observed that this test has proved too much for some of the most heralded inventions.

Since so much reference is necessarily made to patents of invention, it may be well to warn the reader that an invention is not always novel, useful or practicable because it is patented.

While the loose practice of using the words " took out a patent," instead of " was awarded a patent," is to be unequivocally condemned, it must be admitted that the former often express a near-truth, particularly in connection with a new art, and in certain countries.

Patent Office Examiners are only human, and when they accept an application for a patent, it merely means that they know of, and have succeeded in tracing, nothing to upset the inventor's claims. Of course, in large settled countries, where there are specialist examiners for every art or branch of an art, a patent has more significance than it has in a new or undeveloped country, where a few examiners have to deal with applications for patents in relation to all the arts. Moreover, it is a fact that, until a few years ago—and perhaps they exist to-day—there were administrations which would, and often did, take an " inventor's " money for a patent on a " perpetual-motion " or " self-driving " machine. The U.S. Patent Office requires a working model with such applications, which is equivalent to refusal.

In any country a patent of invention is merely a " scrap

of paper" until it has been supported by a law-suit; and it is a wise inventor who knows whom to sue. Being blind, Justice is only too liable to be influenced by a cloud of "expert witnesses," which costs much money.

If over much attention appears to have been given to the arc, it is because, by reason of its simplicity and freedom from patent restrictions, it may continue to have extensive application; even if its present disabilities are not mitigated, which is unlikely.[1]

In the hope that he may thereby help to correct some of the misapprehensions to which expression is so persistently given in the lay press, the author has ventured to look forward a little, and to hazard some opinions on the lines of future development.

Wherever the British or American—as the case may be—"equivalent" of a patent is known to the author, reference is given to it herein. It must not be assumed, however, that such "equivalent" covers the same patent protection in the two countries; because, in many cases, there is a wide discrepancy in this respect. When a patent number is prefixed (or suffixed) by (?), it means that the author has not personally verified the reference.

The author is gratefully indebted to the courtesy of the Commissioner of Patents at Washington, D.C., and to the Controller of His Majesty's Stationery Office at London, for permission to reproduce the extracts from American and British patent specifications respectively, which appear herein; and to the Director, U.S. Bureau of Standards, for the photo and diagrams illustrating the chapter on Beam and Short-wave Radio.

[1] There has been some improvement since this was written.

The author's thanks are also due to Messrs. E. A. B. Snoaden, H. F. White, H. R. Rivers-Moore, and R. E. H. Carpenter of London, for assistance in procuring reference to certain publications, not available in Montreal; and to the Publishers for their courtesy and kindly advice on the arrangement of the subject-matter.

MONTREAL,
December, 1924

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RADIO: BEAM AND BROADCAST

CHAPTER I

THE PAST—TO 1912

IN connection with patents of invention, there is a somewhat commonly used metaphor to the effect that one cannot get a patent on the use of an umbrella to keep off the sun. This, however, cannot be said to apply to the radio art; for instance, J. A. Fleming was awarded a perfectly good patent on the application to radio of a well-known effect and instrumentality; and H. H. C. Dunwoody secured an equally good one on the similar application of a hitherto unsuspected property of carborundum. In each case the invention was of a high order of commercial utility, since the former led to one of the greatest developments in the evolution of the art, while the latter sustained the art during one of the most needy periods of its application to commerce, and is still in extensive use. (See pp. 32 and 36 respectively.)

The evolution of radio has been characterized by comparatively few original inventions of outstanding merit and commercial utility; and by fewer still that, for one reason or another, have found any practical application, until they were about ten years old. Moreover, the borrowings from other arts have been all too few and tardy.

In this chapter we will endeavour to note in chronological order the discoveries and inventions which are more or less strictly relevant to the present state of the art; omitting those which have or had no important practical application, regardless of their academic merit.

1678

Christian Huygens, a Dutch mathematician and physicist, propounded the undulatory theory of light (2).

1843

Professor Joseph Henry communicated to the American Society that he had succeeded in magnetizing needles at a distance of 220 feet (1).

1867

Ruhmkorff perfected the "Ruhmkorff coil" (2), which thirty-five years later was used almost exclusively in wireless stations.

James Clerk-Maxwell propounded the electro-magnetic theory of light (1). This theory confirmed and extended that of Huygens, and was supported by mathematical proofs which form the basis of radio-engineering to-day.

1879

Professor D. E. Hughes, of London, gave a private demonstration of the transmission and reception of radio signals up to a distance of about sixty feet.[1] Those present were W. H. Preece, Sir Wm. Crookes, Sir W. Roberts-Austen, Professor W. Grylls Adams, and Mr. W. Grove. Early in the following year Professor Hughes gave a similar demonstration to a professor of Cambridge, who stated that all the phenomena could be explained by known electro-magnetic induction effects. This so discouraged Hughes that he decided not to publish the results of his experiments until he was in a position to prove that he was making use of hitherto unknown phenomena. Consequently, his experiments were not made public for many years; meantime the phenomena had been identified by others, and commercially applied by Marconi. In 1899, in commenting on Hughes' work, Sir Wm. Crookes said, "It is a pity that a man who was so far ahead of all other workers in the field of wireless telegraphy should lose all the credit due to his great ingenuity and prevision" (1)

[1] It is recorded that Hughes succeeded in signalling over several hundred yards.

(10*a*). In later years Hughes might have had recognition of his work, but he resolutely refused (10*c*).

1883

Professor A. E. Dolbear, of Boston, evolved a system in which he proposed to use an elevated aerial, earthed through the secondary of a Ruhmkorff coil, having a telephone transmitter and battery in series with the primary. He also proposed in 1886 to elevate his aerial by means of a kite and to put a Morse key, instead of a telephone transmitter, in the primary circuit (1) (see U.S. Pats. 350,299 and 355,149, which were acquired by the United Wireless-DeForest-Company) (23).

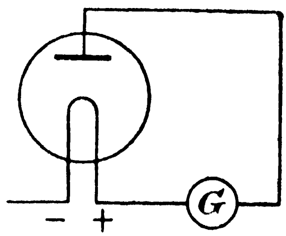


FIG. 1.
Edison's Patent on a Diode for use in the Voltage Control of Electric Lighting Systems (1885).

Thomas A. Edison, of New Jersey, applied for an American patent on a diode for use in the voltage control of electric lighting systems. (U.S. Pat. 307,031. See Appendix, p. 143.) This invention caused considerable scientific interest, but does not seem to have had much practical application. (See Proc. Royal Society, London, Vol. xlvii, 1889-90, p. 118, J. A. Fleming.) (Fig. 1.)

1885.

T. A. Edison proposed the use, in an inductive system of wireless telegraphy, of an elevated and earthed aerial for land stations, and an inverted and earthed " L " aerial for ship stations. (Fig. 2*a*, *b*, *c*.) (U.S. Pat. 465,971.) He also proposed the use of balloons covered with conducting foil and connected through transmitting or receiving apparatus to earth. (Fig. 2*d*.) This invention was acquired by the Marconi Company in 1903 (28).

1888

Professor Rudolf Heinrich Hertz, a German, demonstrated experimentally the possibility of creating electromagnetic waves in the ether, and confirmed their identity with those, which according to Clerk-Maxwell's theory, were the conveyors of light. Apparently Hertz was unaware of Hughes' earlier experiments with a microphonic detector and a telephone, because he (Hertz) used for a detector a simple metallic loop containing a minute spark gap. Hertz succeeded not only in detecting the waves, but in measuring their velocity and length. He also demonstrated that they were capable of reflection, refraction and polarization (6).

1890

Professor Edouard Branly, of Paris, found that a "coherer" was a detector of Hertzian waves. The "coherer" effect had previously been noted and commented on by others, and it had been used by Hughes in his unpublished experiments of 1879. Although it was known at this date that the filings or granules could be decohered by tapping, no automatic provision seems yet to have been made to this end; and it was not until 1897 that Lodge disclosed that when used with a telephone, a filings "coherer" did not require to be tapped.[1]

It is related that, in the course of some experiments to ascertain the conductivity of an iron chain under various degrees of tension, Branly noted sudden current rises, for which there was no apparent reason. In the course of his inquiries for the cause, he discovered that in another part of the building a person was making simultaneous experiments with a Ruhmkorff coil, and that—as we would now expect—there was a current rise in the chain each time the coil came into operation. The writer has not

[1] See p. 130.

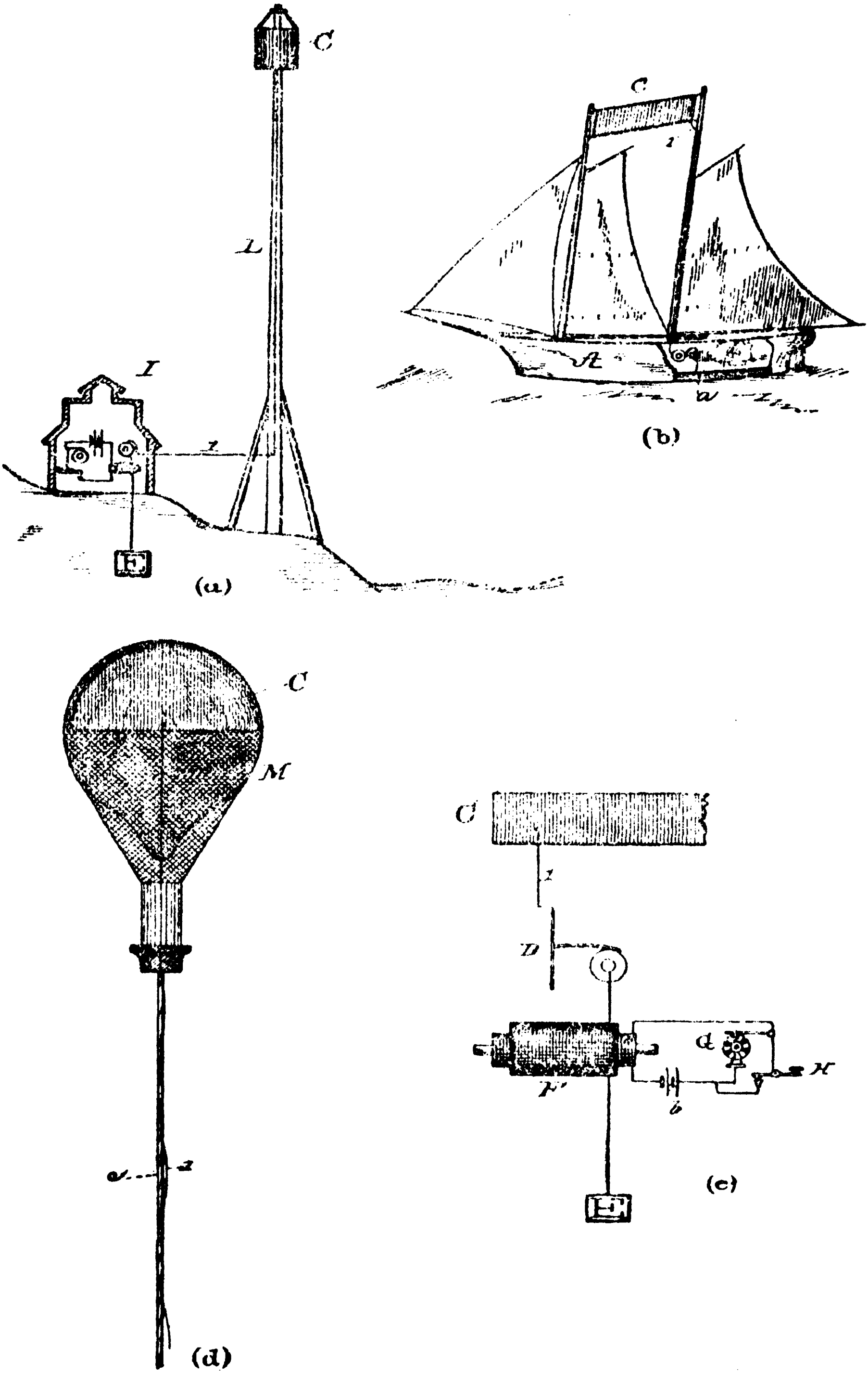


Fig. 2 (*a, b, c, d*). Edison's Inverted and Earthed "L" Aerial (1885).

been able to verify this story. (Branly received the Nobel Physics Prize in 1921 for his researches in Radio.)

Professor (now Sir) Oliver Lodge published the results of his researches and experiments in electrical resonance or syntony, and explained that a closed oscillatory circuit was a feeble radiator and a feeble absorber (5).[1]

1892

In the course of a paper in the *Fortnightly Review*, in February, Sir Wm. Crooks said, "Rays of light will not pierce through a wall, nor, as we know only too well, through a London fog; but electrical vibrations of a yard or more in wave-length will easily pierce such media, which to them will be transparent. Here is revealed the bewildering possibility of telegraphy without wires, posts, cables, or any of our present costly appliances. Granted a few reasonable postulates, the whole thing comes well within the realms of possible fulfilment. At present experimentalists are able to generate electric waves of any desired length, and to keep up a succession of such waves radiating into space in all directions. It is possible, too, with some of these rays, if not with all, to refract them through suitably shaped bodies acting as lenses, and so direct a sheaf of rays in any given direction. Also an experimentalist at a distance can receive some, if not all, of these rays on a properly constituted instrument, and by concerted signals messages in the Morse code can thus pass from one operator to another. . . . At first sight an objection to this plan would be its want of secrecy. . . . This could be got over in two ways. If the exact position of both sending and receiving instruments were known, the rays could be concentrated with more or less exactness on the receiver. If, however, the sender and receiver were moving about, so that the lens could not be adopted, the

[1] See also Appendix, p. 126.

correspondents must attune their instruments to a definite wave-length, say, for example, fifty yards. . . . Even now, indeed, telegraphing without wires is possible within a restricted radius of a few hundred yards, and some years ago I assisted at experiments where messages were transmitted from one part of a house to another without an intervening wire by almost the identical means here described." [1] (A similar suggestion is reported to have been previously made by Professor R. Threlfall, of Sydney, N.S.W.) (1).

Professor Elihu Thomson, of America, applied for a

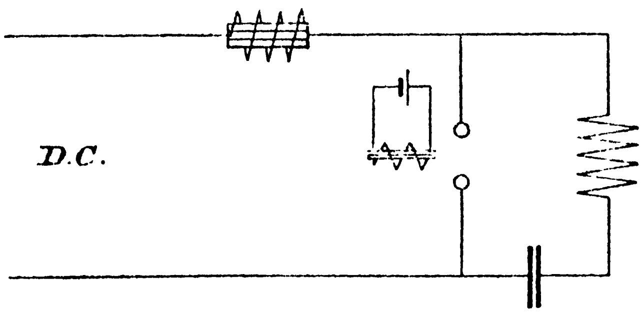


Fig. 3. Elihu Thomson (1892).

patent on an arc method of producing high-frequency currents. His invention incorporated a magnetic blowout and other essential features of the arc of to-day, but the electrodes were of metal and not enclosed in a gas chamber. (See U.S. Pat. 500,630, Appendix, p. 175.) (Fig. 3.)

1893

Nikola Tesla lectured before the Institution of Electrical Engineers in London, on "Experiments with Alternate Currents of High Potential and High Frequency," wherein he disclosed ways and means of generating the currents that were required for radio-telegraphy (4).

[1] See p. 18.

1894

Professor Oliver Lodge transmitted and recorded signals across a distance of sixty yards (10*a*).

1895

Professor A. S. Popoff, of Russia, used a coherer in series with an elevated aerial and ground, with a recorder in shunt with the coherer, for the purpose of studying natural electro-magnetic waves or "atmospherics." His coherer was fitted with an automatic tapper. Commenting upon his experiments (in December, 1895) he said: "I entertain the hope that when my apparatus is perfected it will be applicable to the transmission of signals to a distance by means of rapid electric vibrations—when, in fact, a sufficiently powerful generator of these vibrations is discovered" (1). (Fig. 4.)

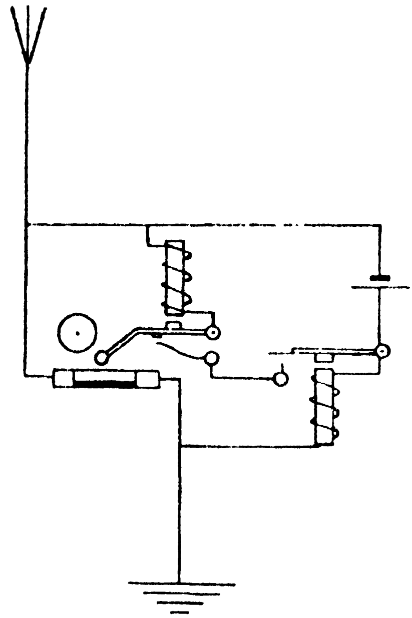


Fig. 4.
Popoff's Receiver (1895).

1896

In June, Professor Ernest Rutherford, of Cambridge, succeeded in receiving signals over a distance of half a mile. In place of a coherer he used a magnetic detector of his own invention (1).

In the same month Guglielmo Marconi filed an application for a patent[1] (British) on an invention whereby

[1] P. 116.

"electrical actions or manifestations are transmitted through the air, earth, or water by means of electric oscillations of high frequency." The provisional specification which accompanied the application dealt chiefly with modifications in the Ruhmkorff coil, the coherer and coherer circuits, and associated tapper. For the "greatest possible distance" of communication, it recommended the use of reflectors at the transmitter and receiver.

In September, Nikola Tesla filed an application for a British patent on "Improvements relating to the Produc-

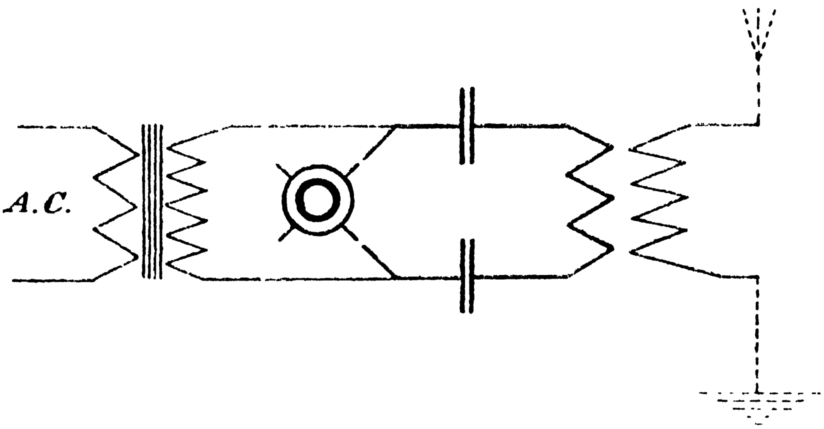


Fig. 5. Tesla's Improvements (1896).
Dotted lines indicate application to Radio about a decade later.

tion, Regulation and Utilization of Electric Currents of High Frequency, and to Apparatus therefor," the latter of which included the synchronous rotary discharger. The application was accepted on the 21st November, whereupon was disclosed a method of producing radio-frequency oscillations, which was the most approved for twenty years. (Br. Pat. 20,981/96.[1]) (Fig. 5.)

(NOTE.—In this year, also, Professor C. W. Röntgen discovered the X-Rays.)

[1] See Appendix, p. 138.

1897

Marconi filed (in March) the complete specification of his invention of 1896. The specification is largely taken up with particulars of modifications in the coherer and other details, but the part which is of chief interest is that which refers to the use of an elevated aerial, earthed at one end. In this connection, the specification says: "The larger the plates of the receiver and transmitter, and the higher from the earth the plates are suspended, the greater is the distance at which it is possible to communicate at parity of other conditions." This does not quite conform with the provisional specification filed in 1896—nine months previously; and, no doubt, it indicates the results of experiments which had been made in the interim. Further on, the specification reads: "Balloons can also be used instead of plates or poles, provided they carry up a plate or are themselves made conductive by being covered with tinfoil. As the height to which they may be sent is great, the distance at which communication is possible becomes greatly multiplied. Kites may also be successfully employed if made conductive by means of tinfoil." The actual use of an aerial, elevated at one end and earthed at the other—an earthed vertical oscillator—marked the beginning of great progress in the art. (Br. Pat. 12,039/96;[1] U.S. Pats. 586,193, and re-issue[2] 11,913.)

In May, Professor Oliver Lodge filed an application for a patent on "Improvements in Syntonized Telegraphy without Line Wires," the main feature of which was the provision of means whereby the frequency of the transmitter and receiver could "be verified with ease and certainty." The complete specification was filed on the 1st of February, 1898. This invention was regarded as of

[1] See Appendix, p. 116.
[2] The life of a "re-issue" terminates with that of the original patent.

such outstanding merit that, in 1911, when the British patent thereon was due to expire, it was (in part and conditionally) extended for a period of seven years—a unique distinction in the history of the art. Upon its extension, the patent was acquired by the Marconi Company, which fact was undoubtedly conducive to a more general recognition of its merits. For instance, in 1916, Fleming says: "Sir Oliver Lodge stated clearly, in a fundamental patent applied for in 1897, the right conditions for conducting syntonic radio-telegraphy and for isolating stations, and the necessity for the employment of trains of feebly damped waves" (4). Whereas, in 1907, he said that, "The full scientific explanation of these principles, covering what is called syntonic telegraphy or the tuning of electrical circuits, were fully given long before the date of Sir Oliver Lodge's 1897 British Patent. For example, they were fully set out in two papers published in 1895 in Germany by Oberbeck (*Wiedemann's Annalen*, Vol. xxv, p. 63) and by Bjerknes (*Wiedemann's Annalen*, Vol. lv, p. 21)." Further, in the same early statement, Fleming tells us that apparatus which he had made in accordance with Lodge's specification failed to work, "while that made in accordance with Marconi's worked perfectly." The apparatus referred to was being demonstrated in Germany in 1900 before the officials of the German Patent

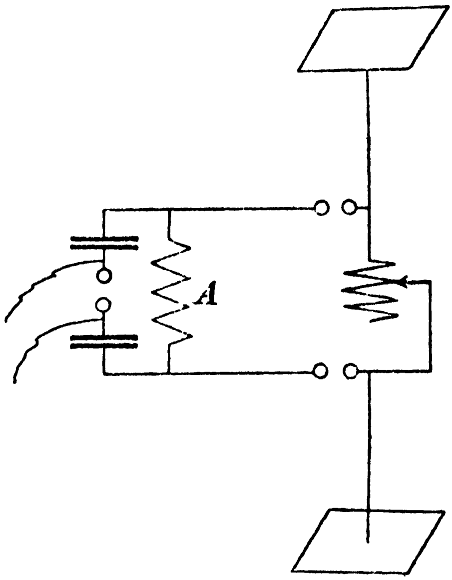


Fig. 6. Lodge's Patent (1897).
("A" primarily for charging purposes.)

Office by Professor Fleming on behalf of the Marconi Company (16). If Fleming's citations were relevant to Lodge's invention of 1897, they must have been even more so to Marconi's of 1900; moreover, they give a greater significance to the earlier inventions of Braun.[1]

In the same reference, Professor W. H. Eccles has said: " During the years between 1896 and 1910, Marconi, aided by Lodge's invention of the tuning coil, carried wireless telegraphy substantially to its present (1922) form " (10*a*); while Professor G. W. O. Howe has said of this invention that " it shows a remarkably clear insight into the problem of tuning and selectivity. It constitutes a great advance on Marconi's patent of the previous year " (11*c*).

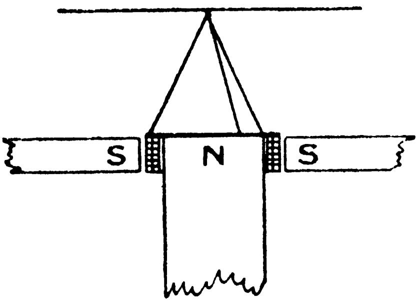


Fig. 7.
Lodge's Loud Speaker (1898).

As instancing the basic nature of the invention, it may be mentioned that the British Admiralty have recently been condemned by Lord Moulton, as Arbitrator, to pay compensation in the nature of royalty to the patentee thereof, on the basis of user throughout the whole period of the life of the patent—twenty-one years. This patent, therefore, has the further distinction of being the earliest British Patent, relating to syntonic radio, to be so confirmed as of a basic nature. (Br. Pat. 11,575/97;[2] U.S. Pat. 609,154.) (Fig. 6.)

1898

In the complete specification of the invention last referred to, Lodge pointed out that it was not necessary to have a spark gap in the aerial circuit. He also disclosed

[1] P. 29.
[2] See Appendix, p. 124.

'or the first time, a receiver inductively coupled to the ıerial circuit.

In the same year, Lodge invented a Loud-speaker, using the now well-known device of a coil connected to a diaphragm and floating in a strong magnetic field. (Br. Pat. 9,712/98). (Fig. 7.)

1899

S. G. Brown obtained a patent on a method of directional transmission and reception. The method involved the use of two aerials, a function of a wave-length apart, which aerials might be looped together. The specification also disclosed the use of a rotary interrupter, whereby a musical note would be obtained.[1] (Br. Pat. 14,449/99.)

Ferdinand Braun obtained patents on a transmitter designed to radiate longer waves than those radiated by the Righi or usual type of oscillator. To this end he proposed a closed oscillatory circuit, containing Leyden jars and induction coils, inductively coupled to a radiating circuit. This use of coupled circuits in the transmitter constituted a very important advance, but Braun did not specifically claim it, or he could have held the whole art to ransom. (Ferdinand Braun, who shared the Nobel Prize with Marconi in 1909, died in Brooklyn in 1918.)

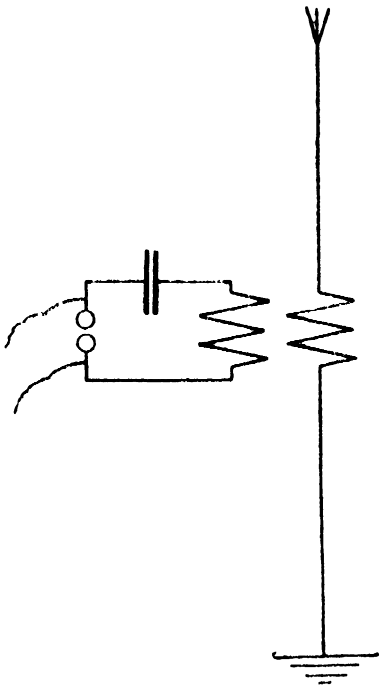


Fig. 8.
Braun's Transmitter (1899).

[1] As it would by Edison's device of 1885. See p. 21.

(See Br. Pat. 1,862/99; German 111,578/98; also Br. Pat. 22,020/99.[1]) (Fig. 8.)

1900

In April, Guglielmo Marconi applied for a patent on an invention which comprised practically all that was in the 1897 invention of Lodge and the later inventions of Braun, and a little more. At the transmitter, he employed separate oscillating and radiating circuits, coupled to each other; and at the receiver, separate absorbing and oscillating circuits similarly coupled; all circuits being tuned to the same frequency or harmonics of that frequency, and (inferentially) sufficiently loosely coupled to enable them to oscillate in resonance. This patent was made the basis of several successful infringement suits, and when it was strengthened by the acquisition of Lodge's 1897 patent it gave the Marconi Company for a time almost a monopoly of syntonic wireless telegraphy in England and America. (Br. Pat. 7,777/00;[2] U.S. 763,772.) (Fig. 9.)

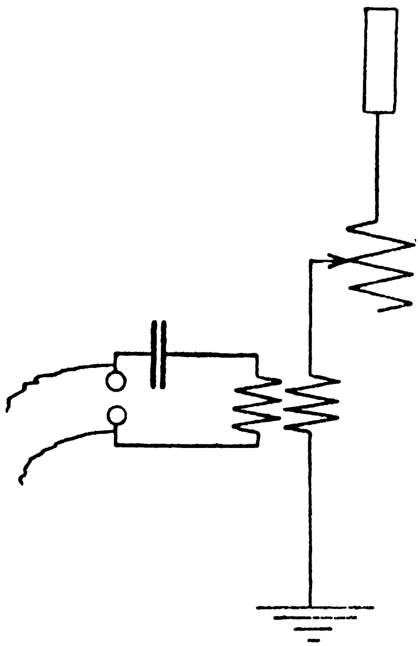


Fig. 9.
Marconi's Patent (1900).

William Du Bois Duddell, of London, applied for a patent on a static method of generating alternating currents from a direct-current supply, which method followed very

[1] See Appendix, p. 132.
[2] See Appendix, p. 134.

closely upon the lines of that of Elihu Thomson of 1892. Duddell suggested electrodes of carbon, but he proposed no magnetic blow-out. He stated that his invention could be used for producing oscillations of high frequency and constant amplitude, which could " be used with advantage in wireless telegraphy," especially where it was " required to tune the transmitter to syntony." Duddell's invention (Br. Pat. 21,629/00 [1]) became the basis of the Poulsen Arc, and also of an interesting transmitter evolved by Von Lepel.

1902

G. Marconi invented an improved form of magnetic detector (Br. Pat. 10,245/02). This detector constituted a great advance on the coherer, and it had a wide application until the advent of the Fleming Valve (Diode), the Crystal and Electrolytic Detectors.

R. A. Fessenden was awarded a patent covering broadly the voice modulation of " practically " continuous waves. (U.S. Pat. 706,647; Br. Pat. 17,706/02.)

1903

Valdemar Poulsen, of Copenhagen, successfully applied for a patent upon a generator, as disclosed by Duddell in 1900, plus the magnetic blow-out proposed by Thomson in 1892, and a hydrogenous vapour in which to immerse the arc. (Br. Pat. 15,599/03;[2] U.S. Pat. 789,449.) Reference will be made later[3] to this invention, which was not commercialized for some years. (Fig. 10.)

R. A. Fessenden invented the method of telegraphing

[1] See Appendix, p. 177.
[2] See Appendix, p. 180.
[3] See p. 75.

by changing the frequency of the transmitted wave. (Br. Pat. 28,290/03.)

1904

On January 15th Dr. A. Wehnelt obtained a German patent (No. 157,845) on a two-electrode vacuum tube rectifier of alternating currents. The filament or cathode of Wehnelt's device was coated with oxide, similar to those

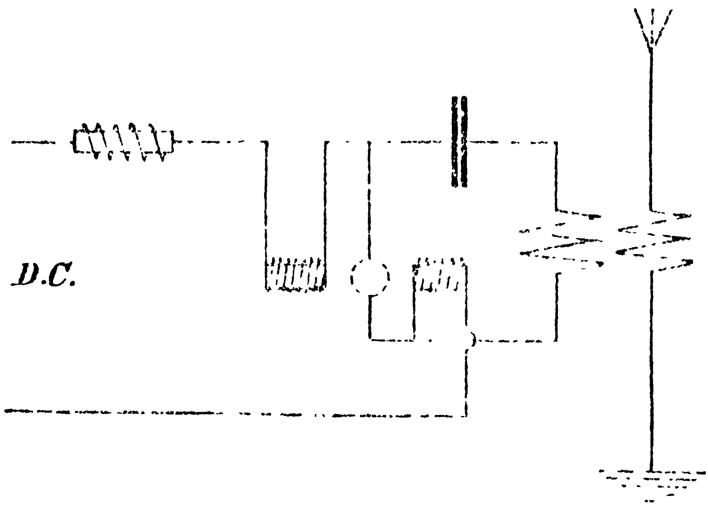


Fig. 10. Poulsen Arc Generator (1903).
Showing "coupled circuit," re-introduced in 1924.

incorporated in the inventions of Von Lieben in 1911 [1] and Franklin in 1913 [2] (15).

On November 16th Professor J. A. Fleming, of London, applied for a patent on the use, in connection with radio, of a vacuum valve or diode very similar to that described by Edison in 1883. According to his specification, Fleming had "discovered that if two conductors are enclosed in a vessel in which a good vacuum is made, one being heated to a high temperature, the space between the hot and cold conductors possesses a unilateral electric

[1] See p. 45.
[2] See p. 158.

conductivity." While it is true that Edison was making use of the limited rather than the unilateral conductivity of the gaseous path, there is evidence both in the preamble and the claims of his specification that he was aware of the asymmetry of the conductivity; moreover, the property had been publicly discussed long before 1904 by Fleming and others, including Elster and Geitel.

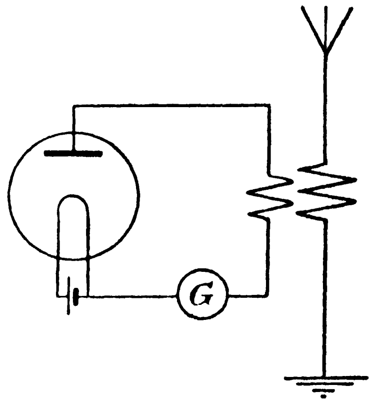


Fig. 11.
Fleming's Diode (1904).

As disclosed by Fleming's specification, the diode was not a very satisfactory detector. Its importance lay in the fact that it was one step in the evolution of the triode rather than in its own utility. The patents on the diode became the property of the Marconi Company, and after the specification of the British Patent had been amended by disclaimer[1] an unsuccessful attempt was made to secure an extension. (Br. Pat. 24,850/04;[2] U.S. Pat. 803,684.) (Fig. 11.)

1905

R. A. Fessenden, of America, applied for a patent on a " beat " or " interference " method of detecting continuous and other Hertzian waves. The invention provided a method, rather than an instrumentality, and there being few, if any, continuous-wave stations then in commercial operation, little use was made of it for some time. Nevertheless, the invention was undoubtedly one of the most meritorious in the history of radio, and it now has a very wide application. (U.S. Pats. 1,050,441 and 1,050,728,

[1] The U.S. specification was similarly amended.
[2] See Appendix, pp. 144, 146-7.

granted in 1913; Br. Pat. 6,203/07. See also U.S. Pat. 1,141,717 to Lee and Hogan in 1915; Br. Pat. 24,458/13.)

G. Marconi applied for a patent on an inverted "L" aerial. The directional property of this aerial, which, according to the specification, was equally pronounced in transmitting and receiving, has been acclaimed by Fleming and many others. (This, by the way, is not to be confused with the "Marconi Beam.") The specification states, "This receiver may be used with great advantage to determine the direction of a transmitter, say, for instance, on a ship at sea," and explains that if "such an antenna be swivelled about its detector end in a horizontal plane, and signals be received with the antenna in a certain position, the operator will know that the transmitting station is in the line of the antenna; in other words, that its tail end is pointing directly away from the transmitting station."

As to the directivity of this type of aerial for transmission purposes, there seems to be a great conflict of opinion; and despite what has been said to the contrary, it appears that when such an aerial is high enough to be an efficient transmitter, its directivity is negligible, except perhaps when the ratio of distance to wave-length is very small.

Such a directive aerial as Marconi claimed this to be, would be invaluable for long-distance point-to-point stations, like those proposed for the British Imperial Chain. However, the 1922 report of the Wireless Telegraphy Commission (Technical) recommended for these stations aerials of a symmetrical type (24).

T. L. Eckersley tells us that the directive effect of an "L" aerial "is a very small amount" and is almost entirely destroyed when the earth screen is used (7*b*); while Professor Fleming states that theory points to the fact that "any bent oscillator, however arranged, has no asymmetry

of radiation for very large distances" (3). However, in *The Times Engineering Supplement* of March, 1919 (some years later), Fleming tells us that such a directional aerial "is now generally employed in long-distance high-power stations which are intended to communicate with a corresponding distant power station," and that it radiates most strongly in its own plane and away from its open end.

Marconi further points out in his specification that, while aerials of this type are preferably earthed only at one end, "they may be connected to earth at their tail ends

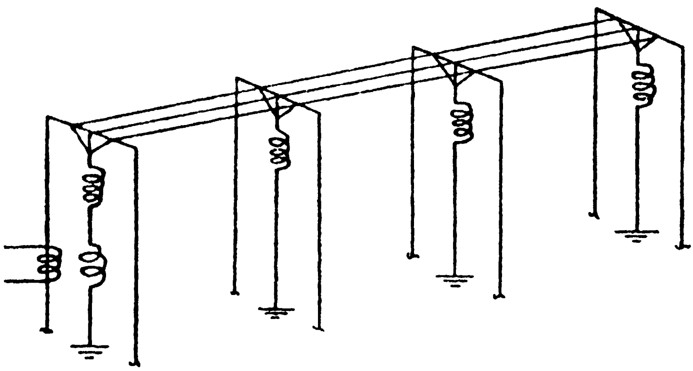


Fig. 12. Marconi's Inverted "L" Aerial (1905).

or at other points, and inductances and condensers may be inserted in these earth connections." (Fig. 12.) This, as has been pointed out by Mr. E. H. Shaughnessy, of the British Post Office, constitutes a pretty full disclosure of the multiply-tuned aerial, which was later patented to Alexanderson[1] (7*b*); but according to C. S. Franklin (7*c*) when "correctly adjusted as regards phase" such an aerial radiates most strongly in a direction at right angles to its length, which is not in accord with the Marconi claims.

In the circumstances, one is not disposed to quarrel with Professor Howe's statement that the action of this

[1] Br. Pats. 130,064, 142,610; U.S. Pats. 1,360,167/8.

Marconi directional aerial is very complex (11*c*). (Br. Pat. 14,788/05. See also Br. Pats. 3,127/06 and 20,230/09.)

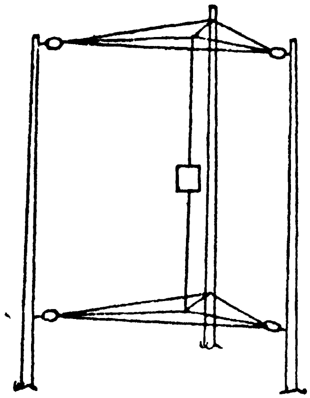


Fig. 13.
Counterpoise Aerial (1905).

A British patent was awarded to W. P. Thompson, as agent for a German firm, on a flat-top aerial with duplicate counterpoise. (Br. Pat. 14,221/05.) (Fig. 13.)

Professor Max Wien, of Germany, invented the quenched gap discharger[1] (Br. Pat. 5,455/05) which is now being increasingly used to replace the rotary discharger of Tesla. (Max Wien received the Nobel Prize for Physics in 1911.)

1906

H. H. C. Dunwoody, of Washington, D.C., invented the carborundum detector and secured a broad patent covering the use, as a detector, of a non-metallic crystalline material. This detector is still very popular, and deserves to be even more so, as it is by far the most simple and reliable for local broadcast receivers. Prior to the advent of the triode, the only serious competitor of carborundum in commercial use was the electrolytic detector, and the former was in far greater favour. Even to-day, carborundum is often used in conjunction with triodes, and it is very effective for short-distance reception, even when used without a " B " battery. (U.S. Pat. 837,616; Br. Pat. 5,332/07.)

G. W. Pickard, of Amesbury, Mass., invented the silicon detector and an efficient way of mounting all

[1] What was practically a quenched gap was patented to T. B. Kinraide of Boston in 1899. (U.S. Pat. 623,316/99; Br. Pat. 5,518/99.)

crystals. Silicon has one advantage over carborundum, in that it is used without a "B" battery, but it is less stable than carborundum. (U.S. Pats. 836,531, 877,451 and 13,798 (re-issue 1914); Br. Pat. 18,842/07.) The U.S. re-issue (expired) referred to above, was especially important because it covered the practice of embedding a rectifying member in a readily fusible metal.

Lee de Forest applied for a patent on the use of a "B" battery in connection with a diode, according to Fig. 14. (Br. Pat. 5,258, March 3rd, 1906; U.S. Pat. 824,637.)

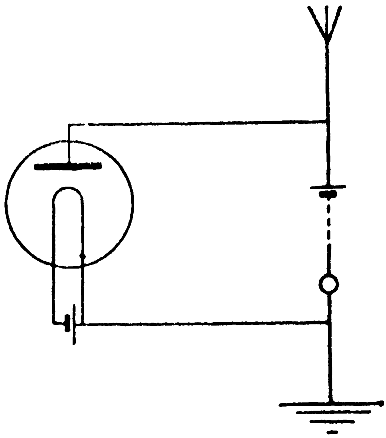


Fig. 14.
De Forest (1906).
"B" Battery.

In the following October, De Forest applied in America for another patent on a triode "for amplifying Feeble Electrical Currents." Figs. 15 and 16 (redrawn) are taken from the specification of this invention, and represent a received signal amplifier and an input telephone amplifier respectively. (U.S. Pat. 841,387.[1]) According to the specification of this invention, in which, by the way, is made the first proposal to use a metal filament, De Forest assumed that it functioned by reason of the relative movement of the

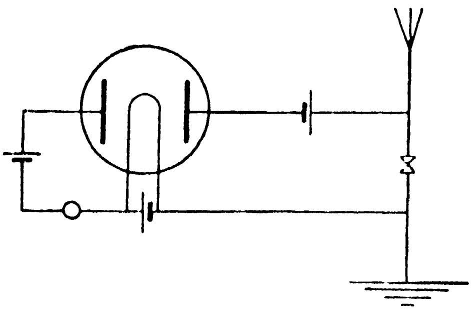


Fig. 15.
De Forest's Triode Amplifier (1906).
Metal Filament.

[1] Expired January 15th, 1924. See Appendix, p. 148.

electrodes under the influence of the currents to be magnified. In the course of legal proceedings in 1916, the American Marconi Company admitted infringement of this patent (15).

In this year Ferdinand Braun disclosed how a heart-shaped polar radiation diagram could be obtained by a combination of aerials (7).

1907

Lee de Forest invented the triode detector (Fig. 17) (U.S. Pat. 879,532;[1] Br. Pat. 1,427/08), which, like its thermionic predecessors, created little interest and had little bearing on the art for several years. Ultimately, however, as is well known, the application and development of the triode revolutionized radio and created a new technique. It rendered many other promising inventions more or less abortive, and caused many thousands of pounds worth of apparatus to be discarded. On the other hand, it provided an instrumentality for putting into practical effect other inventions of importance, such as, for instance, Fessenden's "interference" receiver.[2]

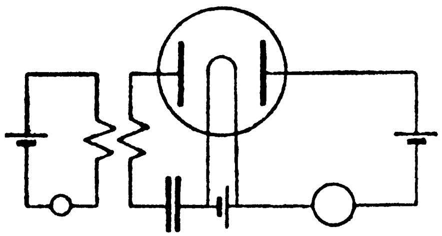


Fig. 16.
De Forest's Telephone Input Amplifier (1906).

In 1911 or 1912, when there became due the first renewal fee on this British de Forest Triode Patent, that fee was not forthcoming, and the patent lapsed. However, as proprietors of the diode patent, granted to Fleming, the British Marconi Company had control of the situation in

[1] Expires February 18th, 1925. See Appendix, p. 151.
[2] See p. 33.

the United Kingdom until 1918, and they would have continued their control had they not been unsuccessful in their attempt to secure the extension of Fleming's patent.

In 1916 the American Marconi Company admitted infringement of this patent (U.S. 879,532 to De Forest) also (15); nevertheless, there has been much controversy —even in some text-books—relating to the value of De Forest's contributions to the evolution of the triode. It has been said that he did not understand the theory of his invention; why or how it functioned as it did. There may

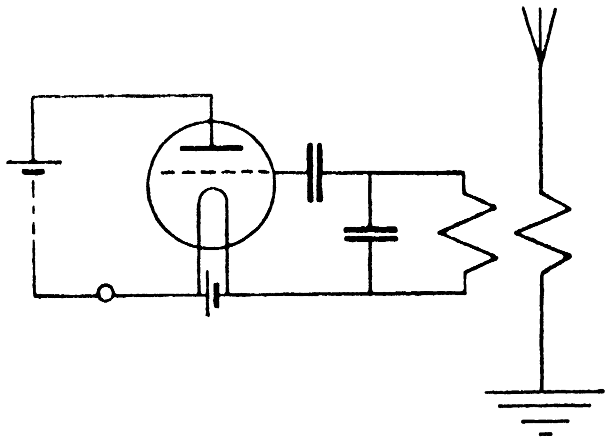


Fig. 17. De Forest's Triode Detector (1907).

be some evidence to support this contention, but what does it signify? With the exception of the specifications of inventions of men like Lodge, Pupin, Elihu Thomson and Duddell, there are few, not of a purely mechanical order, that do not indicate some such lack of understanding. One prefers not to direct attention to examples, but they abound in connection with any new art.

It may be pertinent here to quote a few expert and disinterested opinions on the merit of De Forest's invention. W. R. Cooper, when editor of *The Electrician*, London, said: "In the field of radio-telegraphy Professor Fleming's valve receiver introduced an important principle. An

extension of work in this direction by Dr. de Forest led to the audion receiver, and thence to the audion amplifier. The latter bids fair to play an important part in telephony, and has already rendered it possible to transmit speech across the Atlantic by radio-telephony." (In the same publication, in an article devoted to radio-telegraphy, Professor Fleming concedes that the Fleming valve, " in certain forms," is more sensitive than the magnetic detector; and that " much work has been done in the United States in devising forms of thermionic detectors, all of which are lineal descendants of the Fleming valve ") (4). This was published in 1916.

Professor Howe says: " No single invention has done more to revolutionize radio-telegraphy than that of the audion. Little did Dr. de Forest imagine, when he placed a control electrode first on the outside of the bulb of a Fleming valve and then inside the bulb as a grid between the anode and cathode, that he was making the most important step in the whole history of radio-telegraphy, but such was the case no one can now have the slightest doubt." This is taken from the (Marconi) Year Book for 1921, in which are biographical notes of both Fleming and De Forest. Of the former we read that he was responsible for " a pioneer invention of unusual utility, and one that has enormously aided the development of wireless telegraphy," with which we agree; but no invention is credited to the latter—which is hardly fair.

After making some less flattering comments on the inventions of De Forest, Professor J. H. Morecroft of New York, writing in the *Radio Broadcast* of August, 1922, says: " It is to be pointed out, however, that little as De Forest contributed to an explanation of his device, the thing which he actually did, namely the insertion of the third electrode into a Fleming valve, was a most wonderful contribution to the radio art. As a matter of fact, in the

opinion of the writer, this was the most important single step in the whole development of radio communication. Let us give De Forest credit for this wonderful achievement, even though he was so reluctant to give credit to the other workers in the field, principally Fleming, on whose work the possibility of the audion depended."

With regard to Professor Morecroft's last statement quoted above, it appears that there has been some reciprocity. Moreover, in fairness to De Forest, it should not be overlooked that he also originated the metal filament, the essential " B " battery, and the use of a condenser in series with the grid for detection.[1] In short, he may be said to have advanced the Fleming valve as much as Fleming advanced Edison's device of 1883. The commercial importance of the invention may be judged from the fact that, according to a report of the U.S. Federal Trade Commission, the Radio Corporation of America received orders for 2,931,262 tubes (triodes) in the first nine months of 1923.

It is timely and relevant here to note that on the 12th of January, 1907, G. Marconi filed an application for a patent on the use of an induction coil (10″) as a step-down transformer in the plate circuit of a carbon filament Fleming valve—still without a " B " battery. (Br. Pat. 887/07.) (Fig. 18.) This, Fleming characterized as " one of the best long-distance receivers for electric waves yet devised," and added, " This glow lamp detector has been much used by Lee de Forest, disguised under the name of an audion, and claimed as his own invention " (3). If the reader will refer to the specification of De Forest's British Patent 5,258/06, he will read that, " The present application, therefore, does not cover broadly the employment of these ionized media as detectors, but it has been found by the present inventor

[1] The simple grid-leak is also credited to De Forest (19). See U.S. Pat. 1,377,405; Br. Pat. 100,358(?).

that in order to obtain satisfactory working it is necessary that there shall be included in the circuit of the ionized medium a local E.M.F. . . ." which Marconi's invention lacked.

Ettore Bellini and Alessandro Tosi evolved a very simple and effective system of directional radio, which was of immense use to Britain and her allies during the Great War. H. J. Round, who was very largely responsible for its successful application, says of it: "The Bellini-Tosi idea was so complete that one might say that all the work after the original conception consisted in carrying out correctly the idea and in the improvement of the receiving apparatus. The sensitiveness of the crystal, although greater than either the magnetic or electrolytic detectors, still limited the ranges of reception very greatly on directional aerials" (7). This is also an interesting commentary on the state of the detector art in 1912-14.

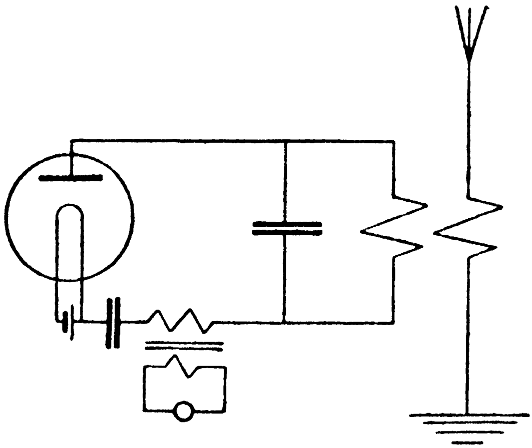


Fig. 18.
Telephone Transformer, Marconi (1907).

Some credit is due to A. Artom, of Italy, for the development of the underlying principle of the direction-finder, as may be gathered from the reference to the specifications of his numerous patented inventions in connection therewith.

The original Bellini-Tosi invention (Br. Pat. 21,299/07; U.S. Pats. 943,960 and 945,440) did not comprehend a "sense" quality, which was not disclosed until the following year by the same inventors. (Br. Pat. 4,801/09.)

NOTICE TO MARINERS

No. **1164** *of the year* 1914

The Astronomical positions are only approximate and the bearings are given both True and Magnetic, and those [illegible] The visibility of lights is that in clear [illegible] during [illegible] [illegible]

IRELAND, EAST COAST.

Lough Larne approach—Abnormal variation.

Position. Hunter rock, lat 54° 53′ N., long 5° 45′ W.

Details. Abnormal magnetic variation has been found to exist in the neighbourhood, and the following cautionary Note has been placed on the charts:—

"*Abnormal Magnetic variation amounting to [illegible] ± 4½° from the normal has been found to exist [illegible] vicinity of Hunter rock and between it and the mainland but the actual limits are not yet defined. Mariners [are] warned accordingly, and the ship's position should be determined by means of sextant angles on objects in transit.*

(Notice No. 1164 of 1914.)

Charts affected. No. 1237, Lough Larne.
„ 2159, Firth of Clyde and Loch Fyne.
„ 45, Lough Carlingford to Lough Larne.
„ 46, Larne to Bloody Foreland.
„ 1577, Western approaches to the Firth of Clyde.
„ 1825*i*, Irish channel, northern sheet.
„ 1824*a*, Ireland, east coast, with Irish channel.

Publication.—Irish Coast Pilot, 1911, page 566.

Authority. H.M. Surveying Vessel *Research*. (S. 1/58 14.)

By Command of their Lordships,
H. E. PUREY-CUST,
Hydrographer.

Hydrographic Department, Admiralty, London,
23rd July 1914.

Agent [illegible] sale of Admiralty Charts [illegible] J. D. P[illegible]
London [illegible]
[illegible] Wt 6[illegible] 56, 750 7 14 [illegible]

[*To face page* 42.

ILLUSTRATING THE IMPORTANCE OF NON-MAGNETIC AIDS TO NAVIGATION.

(J. N. Maskelyne was the first to propose a triangular aerial for directional transmission, but his aerial circuit contained a spark gap and the secondary of an induction coil. See Br. Pat. 7,983/00.)

Dr. A. Muirhead proposed some refinements in the use of the aerial counterpoise, or earth screen, in place of an "earth" connection. (Br. Pat. 11,271/07.) (Fig. 20.) The earth screen has come into considerable use in recent years, but its theory was well developed over a decade ago, particularly by Zenneck (12). British Patent 23,090/04 to J. S. Stone is also relevant.

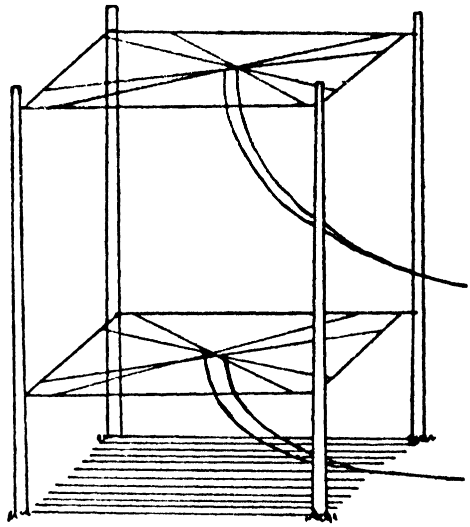


Fig. 20.
Muirhead's Aerial Counterpoise (1908).

R. A. Fessenden proposed the dictaphone method of automatic recording. This method has been very much used in trans-Atlantic wireless telegraphy, and is only now being superseded. (Br. Pat. 20,005/08.) (Fig. 21.)

(Note.—It was proposed by C. L. Chisholm in 1908 to use a dictaphone as a line telephone recorder, the scriber being attached to the telephone diaphragm. See specification of Br. Pat. 9,800/08.)

1908

Professor J. A. Fleming filed an application for a patent on the 25th of June, on a diode having a filament of tungsten and a cylindrical plate of "copper or other

metal." On the 10th December following, he modified this by changing the material of the cylinder to carbon. He also made provision for the "B" battery effect, and secured a patent on the combination on April 15th, 1909. (Br. Pat. 13,518/08; U.S. Pat. 945,619.) (Fig. 22.) Such a device never came into general use, and one is forced to the conclusion that, despite the invention of the triode, the diode at this time was still in an embryonic stage. (It should be noted here that De Forest's application for a British Patent 1,427/08 [1] on a triode having a filament

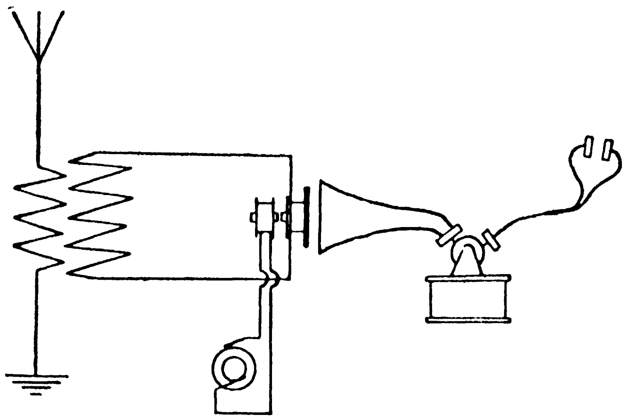


Fig. 21. Fessenden's Method of Automatic Recording (1908).

"preferably of metal" was accepted on April 30th, 1908, and he disclosed a filament of platinum or tentalum in the specification of his U.S. Pat. 841,387 [2] of January 15th, 1907.)

1910

Professor R. A. Fessenden invented a two-tone method of transmitting, whereby dots and dashes could be made of equal length. As a method of economizing "line-time," this invention may yet have considerable application. (Br. Pat. 2,617/11.)

[1] See p. 38.
[2] See Appendix, p. 148.

1911

R. von Lieben, E. Reisz and S. Strauss demonstrated that the triode could be used as a proportional relay of radio-frequency currents. There is little doubt that it was the reduction to practice of the triode by Von Lieben and his associates which restarted triode evolution in other countries. (Br. Pat. 1,482/11; U.S. Pat. 1,038,910.) The use of a "C" battery effect is disclosed in the specification of this patent.

G. Marconi invented a balancing-out method of duplexing spark stations, which marked an important step in the evolution of spark telegraphy. (Br. Pat. 13,020/11.)

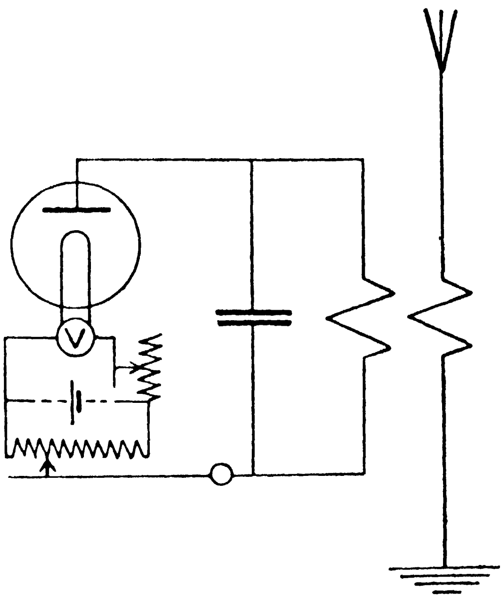


Fig. 22.
Fleming's Diode (1908).
Tungsten Filament. Carbon Anode. "B" Battery Effect.

1912

According to a judgment of the U.S. Court of Appeals of the District of Columbia, dated May 5th, 1924, Dr. Lee de Forest is to be credited with the first invention of the regenerative circuit of the triode on August 6th, 1912. The Appeal Court proceedings were on a long-fought interference and not an infringement issue; and while they were in progress the invention in question was made the subject of many issued patents in different countries: notably to Franklin in England (13,636/13), Armstrong in America (1,113,149), and Meissner in Germany (291,604, April 10th, 1913). The regenerative circuit is one that

involves a certain critical degree of coupling between the two oscillatory systems of the triode, and this coupling may be obtained by mutual inductance (as in Fig. 23), mutual capacity, or mutual impedance, or by combinations thereof. It is variously termed the regenerative, re-active, feed-back or tickler circuit.

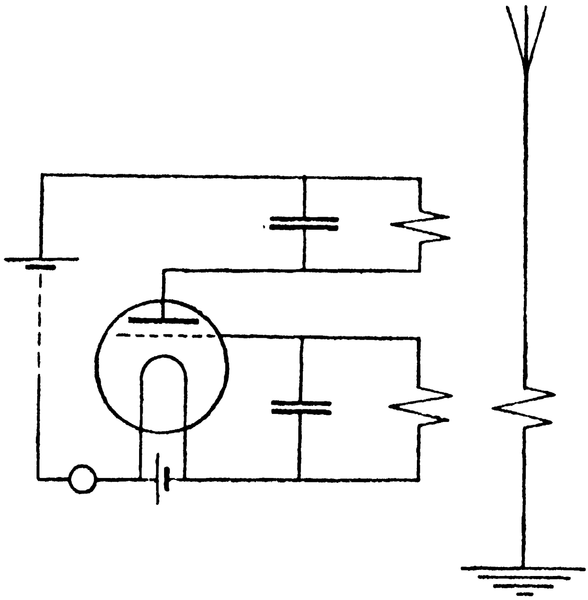


Fig. 23. Regenerative Circuit (1912).

The following is a copy of the judgment[1] :—

" In the Court of Appeals of the District of Columbia

" . . . Before Smyth, Chief Justice; Robb and Van Orsdel, Associate Justices.

" Van Orsdel, Associate Justice: This interference comes here on appeal by the parties Langmuir, De Forest, and Meissner, from the decision of the Commissioner of Patents awarding priority to Armstrong, also appeals by De Forest against Meissner and Langmuir jointly, and against Langmuir individually, for the invention set forth in the following counts :

[1] See U.S. Patent Office Official Gazette, Vol. 324, p. 965, July 29th, 1924.

"'1. Means for producing sustained electrical oscillations comprising an oscillatory circuit having two electrodes in an exhausted receptacle and a second circuit coupled thereto having a conducting body interposed between said electrodes.'

"'2. Means for producing sustained electrical oscillations comprising an oscillatory circuit having two electrodes, a second circuit coupled thereto having a conducting body interposed between said electrodes, and means for varying the frequency of the produced oscillations.'

"'3. The method of producing electrical alternating currents which consists in causing current to flow in one of two coupled circuits and varying the flow of current in the first circuit by impressing the potential induced in the second circuit upon a conducting body interposed between two electrodes in the first circuit.'

"The invention set forth in each of the applications is concisely described in the opinion of the Commissioner as follows: 'All the counts of all the issues involve the setting up of small current variations in one circuit, creating thereby corresponding variations in a second circuit, and feeding back these second circuit variations inductively into the first circuit to add their effect to the initial variations, which latter, thus reinforced, create and form greater variations in the second circuit, and these are, in turn, also inductively fed back to the first circuit to still further amplify the variations in such first circuit, and these still further amplify those in the second circuit, and so on. The energy of the variations in each circuit re-acts upon and increases that in the other circuit until a maximum sustained alternating current is finally produced, whose frequency can be controlled by varying the electric constants of the associated circuits.'

"The whole case, as here presented, turns upon the

question of priority to be determined solely as a question of fact. The Commissioner of Patents, affirming a decision by the Board of Examiners-in-Chief, awarded priority to the party Armstrong. It may be stated at the outset, that the voluminous record in this case is exceptionally free from contradiction or attempted impeachment of witnesses. Indeed, the whole record may be accepted as embracing a true statement of the facts involved in each case.

" Especially are we impressed by the party Armstrong and his witnesses. We have no doubt but what he produced the invention at the time alleged, and did all the things attributed to him by the testimony, as set forth in this record. His earliest claim to a conception of this invention is October, 1912, followed by a witnessed sketch on January 31st, 1913. This date antedates any time claimed by or available to either the party Meissner or Langmuir. These parties, therefore, are eliminated from further consideration.

" This narrows the case to De Forest and Armstrong. It is clearly shown that De Forest was developing the idea involved in this invention in the early part of 1912, and it is claimed that the work culminated in a complete disclosure of the invention in August of that year. If this claim is sustained, De Forest must prevail.

" Coming, therefore, to De Forest's case, the Examiner of Interferences found that in the experiment of August 6th, 1912, the repeating circuit used as an amplifier of telephonic currents was modified by a connection between the plate-filament circuit and the grid-filament circuit. This resulted in the production of 'a beautiful clear tone.' This, the witnesses have testified, was due to the audion generating oscillations or alternating current due to the feed-back action and was understood by them at the time of the experiment. This, it is believed, establishes the

fact that De Forest had a conception of the invention at that time, August 6th, 1912, and that it was disclosed to others. The Board of Examiners-in-Chief after reviewing the testimony held that they were 'not fully satisfied that De Forest really had a conception of his invention in August, 1912.'

"The Assistant Commissioner reviewing the De Forest case, and the experiments made in August, 1912, held that 'it must be conceded this circuit diagram of August 6th, 1912, shows such an arrangement, that if the constants were proper, sustained alternating currents of oscillations would be produced. It is believed, further, the making of the diagram and the production of the "beautiful clear tone" by the apparatus connected up according to such diagram have been fairly proved by the evidence, and that, therefore, such apparatus embodied the issue of this interference. The authenticity of the note-books and diagrams and the proofs as to their dates, as well as the production of the beautiful clear tone at the time alleged, have not been seriously controverted. Clearly the production of the tone was accidental, but this is not of moment. Did De Forest understand what was done, that the tone was due to the feed-back coupling relation, and could he reproduce the tone at will? De Forest states that he understood what was taking place, and both Logwood and Van Etten corroborate him, but he has introduced no record to support this oral testimony given many years afterwards.' He then holds that the failure of De Forest to proceed after August 6th, 1912, with the feed-back circuit until after Armstrong had reduced to practice, entitled Armstrong to priority.

"It will be observed that the Assistant Commissioner in effect holds that what De Forest did in August, 1912, amounted to a reduction to practice, but that after reducing the invention to practice he abandoned it. In patent law

abandonment after reduction to practice is a proposition somewhat difficult of demonstration. At best, however, abandonment under such circumstances is a matter of proof and not of assumption. We think De Forest's record will neither sustain the charge of abandonment nor lack of diligence. The Assistant Commissioner attempts to support his conclusion on the theory that while De Forest unquestionably made this important discovery he did not recognize how the effect was obtained nor did he possess knowledge of how to reproduce it, and that such knowledge, accompanied by simultaneous or subsequent utilization of it in a manner essential to carry out its intended function, is necessary to take the production or discovery out of the class of abandoned experiments.

"De Forest was the inventor of the epoch-marking invention the audion, which he patented both as an amplifier and as a detector. Prior to 1912 he had devoted much of his time to experiments on the audion and to the various uses to which it might be put. At the time he discovered the oscillating audion he was investigating telegraphone recording; the telephone two-way repeater and the amplifier for wireless work. It appears from his note-book records that the first discovery of the feed-back circuit for producing oscillations occurred in connection with his work on the amplifier for wireless and telephone two-way repeater work. There is some testimony, principally from memory, by De Forest and his corroborating witnesses, Van Etten and Logwood, that prior to August, 1912, the oscillating properties of the audion were discovered. It is unnecessary, however, to go behind the written records of August 6th, 1912. This record, with the accompanying drawing, which was made by Van Etten, who was working under the direction of De Forest, clearly shows a feed-back circuit. It also discloses that when connected up it produced oscillations evidenced by 'a beautiful clear tone.'

"The notes and diagrams made by Van Etten on August 6th, 1912, were not copied into the De Forest record book, but it was followed by more complete demonstrations on August 29th, 1912, of which a full and complete record was made by Van Etten in the De Forest record book. The notes indicate that the circuit was tested for amplification with successful results. It is also noted, that reversing the connection to the secondary winding (? of the) coil, all sorts of musical notes were produced in the Brandes phones, and that when the connections are reversed the musical notes, whistle, etc., disappear, and the ticks come through as before. There is no question, both from the disclosure and the testimony of the witnesses, that the circuit produced oscillations of audio frequencies evidenced by the tones in the receiver, the pitch of which could be varied by small changes in the constants of the circuit. While some question is raised as to whether the oscillations were produced by coupling of the circuits of the audion or by means not covered by the issue, we think there can be no question from the evidence supporting the disclosure that the oscillations were produced by coupling of the audion circuits.

"We think the drawing and notes made by Van Etten in August, 1912, clearly disclose the invention as well as the results obtained. The notes trace from the diagram the successful results culminating in the production of the alternating currents. This is not the character of invention where one skilled in the art can draw a diagram and from mere observation theorize a result. No one could even guess how the audion would act in the circuit. It contained an undisclosed secret, an undiscovered phenomenon, which could only be revealed through an actual test. We think the notes contained a complete record of the invention in issue as well as the results obtained. This marvellous invention was not such a thing

as would likely be forgotten by those who witnessed its discovery. Nor does the testimony of the witnesses support either the conclusion that it was cast aside and forgotten, or that their understanding of it was too meagre to permit of its reproduction.

"Indeed, it is conceded, by the opposing parties, that the circuit arrangement, as shown in the record of August 6th, 1912, is a feed-back circuit. It is further clearly shown that oscillations were produced and that the oscillations were produced because of the feed-back circuit. Van Etten testified that the purpose was 'to demonstrate that the audion would amplify minute currents and would be useful primarily in wireless work.' He further testified that the experiment with the audion as an amplifier was deliberately made 'with the expectation and intention of making the audion sing or produce various musical notes and alternating currents.' He also testified that the work was done under the general direction of De Forest, and 'that he was acquainted with the progress of the work.' Speaking of the note-book record, Van Etten said: 'The write-up indicated that in the course of an experiment with the audion as an amplifier, I deliberately turned aside to determine what might be done with the equipment and circuit then available, to produce musical tones and alternating currents.'

"De Forest testifies that in August, 1912, 'the first arrangement was used and disclosed for producing alternating currents suitable for the production of musical tone. The principles involved were discussed and explained; the circuits were clearly understood and recorded, and many observations were made covering the arrangements or changes whereby the pitch and quality of the musical notes thus produced could be controlled.'

"It is generally conceded, indeed as it must be, not only by the Examiner and Commissioner, but by the

parties to this action, that the diagram made in August, 1912, as well as the accompanying notes, not only disclosed the invention but disclosed it in a clear workable manner. So clearly was this fixed in the mind of De Forest that in October, 1912, he returned to New York and there met the witness Stone at the Arts Club. He told Stone of his discovery. Stone procured a piece of paper on which De Forest reproduced the drawing showing the invention, as it appeared in the disclosure made in August. So perfectly did this demonstrate the invention, that Stone, years afterward, when testifying in this case, took a piece of paper and reproduced the drawing while on the witness stand, purely from his recollection of what he had seen in the Arts Club in New York.

"In February, 1913, De Forest returned to California, and on April 17th following, put into actual practice the oscillating audion. In May of the same year he returned to New York, and in June filed an application for a patent for the amplifier and relay, in the hope of raising sufficient funds to commercialize the present invention. He succeeded in September, 1913, in selling to the telephone company the invention for which he filed in June, and immediately wired Logwood in California to join him for the purpose of commercializing the oscillating audion invention. Logwood came to New York, and in October started work towards commercializing the invention. March 12th, 1914,[1] application was filed by De Forest and Logwood for the oscillating audion invention, and about the same time apparatus was manufactured and sold embodying the invention. The present application was filed by De Forest individually, September 23rd, 1915. The subject matter here in issue was the sole invention of De Forest, but it was disclosed in the original joint application of De Forest and Logwood. The facts relative

[1] Author's note. U.S. Pat. 1,170,881; Br. Pat. 3,950/15.

to the activity of De Forest following the discovery of August, 1912, are not only well proven, but they stand undisputed in this record, and we think completely negative any thought of abandonment. They likewise conclusively answer the charge of lack of diligence, if it be assumed that the disclosure of August, 1912, amounted to nothing more than a conception of the invention.

"In this view of the case, it matters little whether the case be disposed of upon the theory that what was done in August, 1912, amounted to reduction to practice or merely conception of the invention. In either event De Forest must prevail. While we think the work then accomplished amounted to reduction to practice, the case can be as readily disposed of upon the ground that De Forest clearly had at that time a conception of the invention and made a disclosure of it to others, since there is nothing to show, under the circumstances disclosed in this record, that he was lacking in diligence.

"Attention has been directed to our decision in the case of De Forest *v.* Miller, 50 App. D.G. 202, where it is urged that we passed upon the sufficiency of De Forest's disclosure of August 6th, 1912. The issue in that case involved a system for producing musical sounds, whereby the pitch and intensity could be so controlled as to produce any note of the musical scale at will, thereby obtaining a musical instrument which produced beautiful clear and sweet musical notes. The claim was very different from the claim here in issue, which calls for 'means for producing sustained electrical oscillations.' The development of the musical instrument did not occur until 1915 when the interference arose between the applications of De Forest and Miller. It was not denied by the Patent Office in that case, that the disclosure of De Forest of August 6th, 1912, amounted to a conception of the invention, but assuming that to be true, it was properly held by the tribunals that

there was a total lack of diligence on his part in developing the particular invention there in issue. Hence that case has no bearing upon the present litigation.

"It is insisted, however, that the question of priority between De Forest and Armstrong was disposed of by the United States District Court for the southern district of New York in Armstrong *v.* De Forest Radio Telephone & Telegraph Co., 279, Fed. 445. That case involved an infringement, and the question of priority, so far as the present interference is concerned, was not there involved. The Armstrong patent there in suit involved a radio signalling system and every claim called for a radio signalling system, and in no respect contemplated the production of 'sustained electrical oscillations.' We are not here concerned with the question of whether the production of electrical oscillations be of radio or audio frequencies, or to what particular use they are put. So remote are the present issues from the claims before the New York Court, that if De Forest had been accorded August 6th, 1912, for reduction to practice in that case, it would not necessarily have anticipated the terms of the claims of the Armstrong patent. Hence the discussion of the New York Court, as to what De Forest did in August, 1912, is merely persuasive.

"The decisions of the Commissioner are reversed and priority awarded De Forest.

"This case was decided prior to the death of the late Chief Justice.

"JOSIAH A. VAN ORDSDEL,
"*Associate Justice.*"

The author has no comment to make on this judgment beyond suggesting that Armstrong's work in radio is such that, had he no patented or patentable inventions—and he has many—he would still rank as one of the foremost exponents of the art.

CHAPTER II

AFTER 1912

With the discovery that the triode could be made to function as a generator of alternating current of any desired frequency, it became apparent that there was a prospect of evolving a radio transmitter that would approximate to the ideal. That prospect has now been realized, and the triode has passed the acid test of commercial application.

Engineers naturally look with some indulgence upon the alternator as a radio-frequency generator, because of its theoretical simplicity; but it seems extremely likely that the triode and its derivatives will not soon be superseded as the keystones of all transmitters of moderate power. Especially is this likely in view of the fact that only one basic technique is involved. Moreover, the triode is quietly revolutionizing the arts of wire telephony and telegraphy, and must soon find important applications to the submarine cable: hence it is proving the greatest factor in bringing about that closer co-operation between the technicians of the various forms of telegraphy and telephony, which is so desirable; and which has had such an enthusiastic advocate in General G. O. Squier.

Technicians appear to have been waiting for the development of the triode and its use as an oscillator in order to put into service many of the inventions and discoveries of the previous thirty years; even including some of those made by Hertz in 1888, such as the use of the short-wave. (Fig. 28.)

Fessenden's interference receiver (or Heterodyne) invention found no commercial application until the triode was available; but at the same time the triode so simplified amplification that it provided an efficient alternative method of detecting continuous waves.

Technically, there is nothing now to preclude the

widespread application of guided-wave telephony, by the use of which most of the benefits of other than graphic arts may be made available to all whose homes are served by an electric-lighting system.

Already commercial telegraphy and telephony have, in many countries, been revolutionized by guided-wave methods, and the use of the triode. Moreover, these two agencies have been the means of saving thousands of tons of copper. Every electrical conductor is now potentially a telephone or telegraph line or both, and it may be the conveyor of grand opera. Appropriate receiving methods are disclosed in the specifications of British Patents 15,718/11 to Erskine Murray; and 3,191/14 to Squier.

Guided-wave telephony, or "wired-wireless," appears to have been first proposed by Hutin and Leblanc in 1892 (Br. Pat. 23,892/92; U.S. application (?) 510,658), developed by them as disclosed in the specifications of their later patents (U.S. 596,017 and 628,246; Br. 2,107/96), and later by Leblanc alone (U.S. Pat. 857,079).[1] The idea is also crudely embodied in the specification of British Patent 1,555 granted to E. G. Foresio in 1900. In later years the method has been developed by G. O. Squier. (U.S. Pats. 980,356, 980,357, 980,358, 980,359; Br. Pat. 30,003/10.)

Guided-wave telegraphy would seem to be the natural evolution of the harmonic systems disclosed by Pupin and others many years ago.

While it would be rash to prophesy that there will be no more startling and valuable inventions in the radio field, it is safe to say that, if none are made and vested interests permit, the development and practical application of the art may steadily progress for many years to come on the basis of present knowledge.

Already speech has been transmitted from a vessel 150

[1] See also J. S. Stone's U.S. Pat. 638,152.

miles at sea in the Atlantic to an island 30 miles off the Californian coast in the Pacific—being relayed over the transcontinental telephone wires; and a regular service —part wire and part wireless—has been open to the public since the summer of 1920.[1] (See Proc. I.R.E., June, 1923. H. W. Nichols and Lloyd Espenschied.)

A comparatively recent practical development consists in the suppression of the carrier-wave[2] and one of the side-bands[3] in radio-telephony. In the author's humble opinion, this marks the culmination of technical advance during the last ten years, although it has not yet had any wide application. In view of present hopes and prospects of dependable, if not continuous, long-distance communication by means of comparatively low-power and short-waves, it now appears likely that a limited secret trans-ocean radio-telephone service will soon be available to the public. (See Proc. I.R.E., October, 1922, and February, 1923, papers by Lloyd Espenschied and R. V. L. Hartley, respectively; also a paper by Dr. H. W. Nichols, Journal I.E.E., London, July, 1923.)

Great inventions, as often as not, are the result of little effort; but the development of inventions so that they may be applied to commercial uses, often entails the closest study and prolonged effort. A classic example is that of the Bellini-Tosi Direction Finder, which, although of great inherent merit, was ten years old before H. J. Round, again with the aid of the triode, made it of immense value to Britain and her allies during the Great War. Round's later work in connection with the development of the

[1] It is understood that, since the above was written, a cable has been substituted for the wireless section.

[2] Patents U.S. 14,959 (re-issue) October 19th, 1920, to De Forest; U.S. 1,449,382, Br. 102,503, to J. R. Carson; U.S. 1,449,392, Br. 146,881, to H. de F. Arnold. Also U.S. Applications 244,839 and 274,288 by Alexanderson and White, respectively (19).

[3] Wave filters. Patents U.S. 1,227,113 and 1,227,114, Br. 142,115, to G. A. Campbell (19). Much of J. S. Stone's early work is also relevant to wave-filters. See, for instance, Pats. Br. 28,826/04 and 9,422/06; U.S. 714,756.

BEFOGGED!

Before the Days of Wireless Direction-Finders

Skipper of "Tramp" (endeavouring to locate his position on an old and filthy chart), "If that's a fly-mark, Bill, we're orl right, but if it's Sable Island, 'eaven 'elp us!"

From Greeting Card of Canadian Marconi Co., 1920-21.)

valve transmitter, although not characterized by any basic invention, is historical.

By a stroke of genius somebody discovered that one of the Bellini-Tosi aerials could be inverted. This meant a very great advantage on shipboard, where it is convenient to have the fore-and-aft aerial with its base uppermost, and the 'thwart-ship aerial with its apex uppermost.

A later development of great importance was an aperiodic aerial, involving tuning of the search-coil circuit only, and thus facilitating the essential expedition of successful direction-finding. (Br. Pat. 149,066 to H. J. Round and G. M. Wright.)

Efficient modified forms of direction-finding apparatus which have found wide practical application have been evolved by J. Robinson in England (Br. Pats. 134,342, etc.) and by F. A. Kolster in the United States (Br. Pat. 138,318), the former being particularly applicable to aircraft.

A frequent bone of contention in radio patent litigation is the grid leak. (See Patents, U.S. 1,282,439, Br. 147,148 to Langmuir; and U.S. 1,377,405 to De Forest.) In a somewhat lesser degree, questions arise regarding the " C " battery or the application of a steady voltage to the grid of a triode. (See Patents, Br. 1,482/11; U.S. 1,038,910 to Von Lieben et al; U.S. 1,231,764 to Lowenstein; U.S. 1,282,439 and Br. 147,148 to Langmuir; Br. 13,248/14 to Round; and U.S. 1,426,754 to Mathes.)

The growing use of tuned radio-frequency amplification lends a particular interest to British Patent 8,821/13.[1] (U.S. Pat. 1,087,892 to Schloemilch and Von Bronk.) This patent is equally relevant to the modern practice of " reflexing," or amplifying both audio and radio-frequency in a single triode.

[1] See also Patents, U.S. 1,173,079, Br. 147,147, to E. F. W. Alexanderson, and U.S. 1,282,439, Br. 147,148, to I. Langmuir. See Appendix, p. 155.

Undoubtedly one of the greatest feats of radio-engineering within the last few years has been the development of distortionless modulation—over the whole gamut of orchestral frequencies—of energy calculated in kilowatts.

There have been many refinements in receiving arrangements; mostly involving the basic inventions of the triode, heterodyne and regeneration, in combination with directive aerials and note-tuning.

In 1919 Professor L. A. Hazeltine, of the Stevens Institute of Technology, Hoboken, N.J., evolved the "Neutrodyne" method of reception which has become extremely popular. (U.S. Pats. 1,450,080 and 1,489,228.) It has been claimed by those interested, that the following patents are also relevant to the "Neutrodyne" method, namely, U.S. 1,183,875 to Hartley; and U.S. 1,334,118, Br. 119,365 to Rice (19).

Another receiving method which has lately become very popular, particularly in America, is the Super-heterodyne. In this method the "beat" is adjusted to and amplified at a convenient and usually definite supersonic frequency. See Patents (British) 133,306, October 1st, 1918, to L. Levy; 135,177, June 18th, 1918, to Siemens and Co.; and 137,271, December 30th, 1918, to E. H. Armstrong. The dates are all Convention Dates.[1]

Despite the oft-recurring reports of their slaughter, "atmospherics" are still the bane of Traffic Superintendents. Nevertheless, if, as one supposes, they (the atmospherics) are merely additive, it seems certain that someone will find a way to avoid their interference with the signal that is always there. Meantime, by means of directive aerials, sharp tuning, and proportional recorders, their effects are greatly mitigated.

Fading is still with us, and its cause remains to be discovered.

[1] See also Br. Pat. 252/14 to von Arco and Meissner, p. 172.

Freaks also remain to be explained. Dr. W. H. Eccles has suggested that they are the equivalent of the mirage in optics, and that as such, they are a law unto themselves (7*d*).

It is appropriate here to note the fact that in 1920 there passed away one of the earliest workers in the field of wireless telegraphy (11*c*), in the person of Senator Augusto Righi, under whom Marconi studied at Bologna. Apropos of recent short-wave developments, it is recorded (1) that, over twenty-five years ago, Righi succeeded in generating Hertzian waves of a length of only 2·5 centimetres.

(The following works of Righi will be found in the Library of the British Museum in London and in the New York Public Library: A paper entitled "Sulle oscillazioni elettriche a piccola lunghezza d'onda, etc.," published in 1894; a book entitled "L'Ottica delle oscillazione elettriche,"[1] published in 1897; and another entitled "Fenomeni elettro-atomici," published in 1918.)

Some idea of Righi's character may be obtained from the following tribute paid to him by his friend Augustus Trowbridge: "Righi's friends appear to have been jealous lest he should fail to receive proper credit for his part in making wireless communication possible; but not so Righi himself, who cared little for popular applause and actually enjoyed a fuller measure of it in his own country than ordinarily falls to the lot of a pure scientist" (17).

[1] In German in New York.

CHAPTER III

THE FUTURE

WHATEVER the future may have in store, it seems unlikely that there will be any great improvement in results, but rather in their dependability and the methods of obtaining them.

Inventive genius will naturally be directed towards effecting economies in the ether, in connection with which serious problems are already arising. It is inevitable that there will be great developments in note-tuning, and it may be that modulation or "chopping" of telegraph signals will be effected at the transmitter. In such case, transmitting stations will be licensed as to both the radio and audio-frequency characteristics of their signals.[1]

Meantime, considerable economies of "line-time" could be effected on the congested 600-metre wave in the North Atlantic, by the elimination of the words "Latitude North, Longitude West," from the positions which are signalled to shore, and which constitute a considerable proportion of the traffic on that wave. "Latitude" is invariably given first, and most of the ships regularly in the North Atlantic trade are never in *South* Latitude or *East* Longitude. A rule might therefore be established that Latitude will, as now, always be given first, and that the four words quoted above will be deleted, excepting when a ship is in *South* Latitude or *East* Longitude, where (except in the North Sea) the ether may be less congested.

There are already available very highly tone-selective receivers, relays and recorders; and when, as seems likely, in some cases ships will be required to transmit certain specified wave-train frequencies only, such devices will find a wide application. There are numerous methods—electrical, mechanical, acoustic, and their combinations—of adding the refinement of note to wave-tuning; but their

[1] The possibility lends a special interest to Br. Pat. 155,854 to W. H. Eccles and F. W. Jordan.

applicability, and consequently their development, has been retarded pending greater stability of note-governing conditions at the transmitter. The author has seen the Hall Air-Jet Relay (Figs. 23 and 24) (U.S. Pat. 1,160,072; Br. Pat. 144,250) satisfactorily operating a recorder, through jamming which made it almost impossible for a trained ear to read the desired signals.

Beam signalling will undoubtedly find extended use, and being presumably free from vital patent restrictions, is sure of rapid development; particularly for short distances. It will be especially useful for conversation

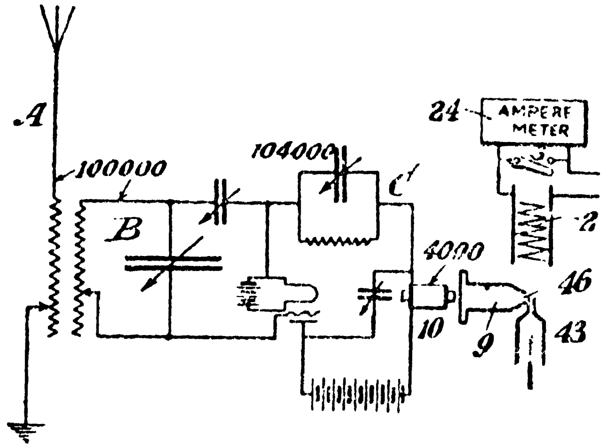


Fig. 25. Hall Air-Jet Acoustic Relay.
(Hot Wire Type.)

between ships in sight of each other, at sea; for aids-to-navigation purposes; and possibly in land warfare.

It has already been proposed to use as a conductor or aerial a beam of waves of the frequency of ultra-violet light, and such a beam may come to be utilized to guide a carrier wave. (Br. Pat. 124,833 to J. Hettinger.)

" So, Engineers, observe a Wave
Hath smaller Waves that on him ride,
And these have smaller Waves to ride 'em,
And so proceed *ad infinitum.*"

So one may paraphrase Dean Swift and epitomize the technique of radio-telephony.

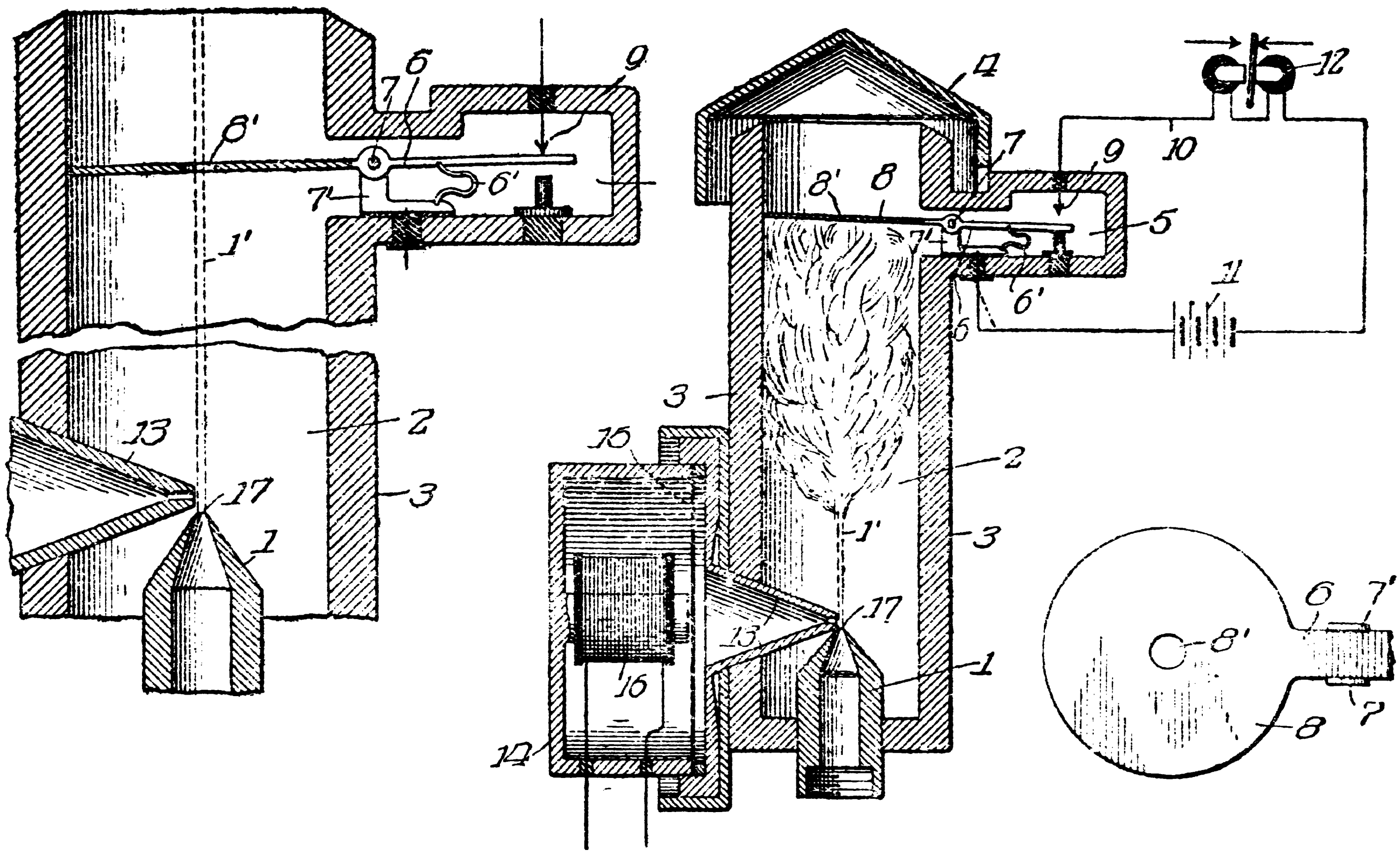


Fig. 26. Hall Air-Jet Acoustic Relay. (Contact Type.)

The triode, as we know it, will undoubtedly undergo considerable evolution. De Forest and others have proposed various forms of hot cathodes, and it may be that an arc will come to be used as a cathode in the larger-powered triodes of the future; in fact, this is suggested in the specification of De Forest's British Patent 5,258/06. On the other hand, it has been suggested that the hot cathode may some day be dispensed with.

There is very much work for the research engineer of the future in discovering the hidden causes of the many known phenomena; and for him, as for most of his predecessors, success is likely to be its own reward.

We have yet to learn why radio waves persistently ignore certain spots in their great-circle path to others more distant, where they arrive with no abnormal attenuation. Cases are too numerous and too well known to be worth citing. It seems hardly reasonable to suppose that a "Heaviside Layer" or any other celestial reflector is sufficiently stable, as regards position and plane, to work consistently for the benefit or otherwise of certain spots.[1]

We do not know the cause of fading. It could be accounted for by a variation of wave-length due to the equivalent of winds in the ether; just as the pitch of the whistle of a passing locomotive will vary with the growth and decay of the speed (and frequency) of the sound waves, as their source approaches and recedes; but there is no proof that fading is so caused. According to Fleming, "No experiments yet (1921) devised have enabled us to determine any motion of this hypothetical æther relatively

[1] In his 1924 Kelvin Lecture at the Institution of Civil Engineers, London, Professor Elihu Thomson enunciated the theory that a "Heaviside Layer" was unnecessary, since all radio waves were guided by the earth, which was the real conductor; just as was the wire, in guided-wave telephony or telegraphy. He illustrated his theory by saying that the ideal condition for radio would be a smooth copper earth in a vacuum. This theory seems to be well supported by the well-known fact that much greater distances are possible over water than over land, but it is believed to be unpopular with mathematicians.

to the earth or any other moving matter," and he quotes Professor Eddington as declaring that "the æther must now be regarded as an idle hypothesis unsupported by experiment and giving explanations of nothing" (10*b*).

If one may not postulate ethereal winds, a reflecting layer, or even an ether, there is only the "passing shadow" theory to account for fading unaccompanied by freaking;[1] but when fading alternates with freaking, the cause would seem to be transient interference and co-operation of direct and diffracted waves, which inevitably bespeaks a layer.

Given adequate power, there is every reason now to believe that dependable, if not continuous, communication by radio-telegraphy may be effected between any two points on the earth's surface; and that between relatively antipodean stations, communication should be particularly dependable. In fact, in the near future, there will probably be an "antipodean" station in every country—almost certainly in every continent. The receiving component of each will be equipped with a number of vertically plane-polarized and "sense" selective aerials, arranged radially about the operating house; so that regardless of the direction of approach, or the phase of the incoming waves, their energy may be summated in the received signal. In short, it is not unlikely that the most dependable, really long-distance, communication of the future will be effected between stations that are approximately "poles apart."

Obviously, transmitting stations of such relative location would be of the "Broadcasting" kind; as any attempt to use directional transmission would tend to the sacrifice of the special value of broadcasting for such communication. Moreover, for highest efficiency, a directional transmitter would require to be continuously oriented.

There is not yet any ground for supposing that

[1] By which is meant the reception of signals of excessive strength.

"beam" transmission will ever be practicable or useful for antipodean or even long-distance communications; but there is good reason to suppose that the high-powered long-wave transmitter of the future will be supplemented by a short-wave comparatively low-powered transmitter for auxiliary night communication, particularly where the route of communication has a diurnal all-dark period. It is perhaps not sufficiently well remembered that no two spots on the earth's surface are more than 12,500 statute miles apart; or that two broadcasting stations of this range, and suitably disposed, could sweep the earth.

Meantime, the cables are not threatened,[1] and where efficient cable services are available it is very debatable whether or not it is economically sound to operate wireless, except as a supplementary or standby measure.

It may transpire that, on account of the uniformity of conditions of light, long-distance wireless services will tend to be restricted to longitudinal routes.

The wave-lengths allocated to broadcasting and amateurs have proved so efficient for night communication that an attempt may be made to reclaim them for commercial telegraph purposes during the night hours—say from midnight to 6 a.m.; especially is this likely since the very long waves now in use for telegraphy tend to impose a limitation upon the speed of transmission. According to recent reports, the allocation of a band of short waves to commercial radio-telegraphy seems now to have been definitely decided upon.

It is unlikely that there will be any wide application of radio-telephony to public service beyond broadcasting. The average broadcasting station occupies as much of the ether as would accommodate ten radio-telegraph stations—possibly more; and the ether is already becoming con-

[1] This may need qualification when exhaustive long-distance tests have been made with very short waves.

gested. The suppression of the carrier wave and one of the sidebands would effect an economy of the ether of about 50 per cent. (and also of transmitting energy), but stations operating under such economical conditions would be unintelligible on the broadcast receivers now generally in use.

In the near future, broadcasting of local urban interest only will likely be effected over existing wire (lighting or telephone) systems, and so kept out of the ether. Stations broadcasting entertainment, etc., of wider interest, will probably extend their present practice of "tying-in," or broadcasting the same programme simultaneously from several stations; with a resultant improvement in the quality of programme.

Already it is possible to set up an audio-frequency electro-static field, so that a person may listen to a broadcast programme by means of a pair of head-telephones having no fixed attachment; and may even hear the programme in any part of a room. (Br. Pat. Application 16,442, 25th June, 1923, Hale and Lyle.) This device may come into extensive use in private houses, hotels, restaurants, ships and trains, where "loud-speakers" are not desired. The electro-static field is set up by a conducting grid which may be in the form of a mat under a carpet, the metal lathing of a ceiling, or the spring of a bed or chair, connected to one terminal of an audio-frequency amplifier, the other terminal of which is connected to earth or a suitably disposed counterpoise or second grid.

When the "loud-speaker" is more nearly perfected, there is no doubt that it will be used in hotels and ocean liners to make orchestral music available in a number of public rooms. For instance, on a liner, the orchestra that plays for the first class passengers will be made audible to those of the second and third class.

For the last twenty years or so, the ultimate authority on radio matters has been vested in a league of nations—if one may borrow a term—with headquarters at Berne in Switzerland. For the use of this body a common language had to be adopted; and, according to precedent, French was chosen. Obviously, therefore, radio has long been a factor in social evolution in the broadest sense; and to-day the practice of " Broadcasting " opens up further new and wonderful opportunities in this direction. To realize what a great opportunity radio now affords to people of good sense and goodwill, one has only to consider that one station in Europe may provide instruction and entertainment for people of twenty different races, tongues and religious prejudices. What an opportunity also for the advocates of Volapuk, Ilo, Esperanto, or other would-be lingua franca!

There is little doubt that one of the effects of " Broadcasting " will be the condemning of the spark transmitters now in use on shipboard, because of their interference. Alternatively, their use within a given number of miles of a broadcasting station may be forbidden.

At the moment the radio and shipping worlds most urgently await an automatic distress-call receiver. It must be one that is acceptable to all nations, and that will not necessitate expensive or intricate gear at the transmitting station. If it should appear advisable, there is no doubt that the international distress call-signal would be modified or materially changed to suit any practicable device. The question presumably now awaits the universal adoption of continuous-wave transmitters aboard ship, or the next International Conference.

In the author's opinion, the ultimate distress-call will be made up of signals of two or three different notes or wave-train-frequencies, used either simultaneously or successively. In such case, the automatic receiver will

consist of two or three tone-selective switch-closing elements, inoperable by anything but the distress-call, and self-resetting.

As an alternative or additional measure, a special wave may be allotted exclusively to distress-calls, particularly in busy areas, and a definite number of suitably located listening stations established to stand-by permanently on that wave. Each of such "Distress" listening stations will be equipped with direction-finding gear, so that the distress-call may be confined to the ship's call letters or any other signal on the prescribed wave.

If such a scheme were adopted, shipboard transmitters would have to be designed to provide instantaneous change-over to the "distress" wave, and for maximum efficiency thereon. Ships unfurnished with operators would be permanently tuned to the "distress" wave, and would be provided with code-wheels or other suitable automatic transmitters, and explicit directions for their use.

Upon receipt of a distress-call, the distressed ship's position having been located by means of cross-bearings, the controlling coast-stations would be notified immediately to suspend all traffic on the commercial waves until definite arrangements had been made for the assistance of the distressed ship; meantime, certain extra ship or coast-stations would stand-by on the "distress" wave.

It may be found desirable to have ships' distress radio-transmitters tied-in to simultaneously operating submarine sound transmitters,[1] so that (if she were equipped with apparatus to measure the difference in transit-time of the two signals) an approaching ship could calculate the distance of the signal source. That such a method has often been proposed may be gathered from a reference

[1] Borkum Riff Light Vessel, Germany, is now experimentally equipped in this manner.

to the specifications of the following British Patents: **12,124/99** to C. F. Kelway (Ether and Air); **10,082/09** to J. Schiessler; **25,318/10** to E. F. Cassel; **4,352/14** to A. Stchensnovitch; **7,452/15** to F. L. Sawyer; and **146,125/19** to R. L. Williams.

One very gratifying thought for those who have been associated with radio for the last two decades or so, is that it is now practically impossible to lie about it. Of course there will continue to be exaggerated claims and wild statements when, in the opinion of some of those concerned, occasion arises. For instance, it is doubtful that the fetish that radio will supplant conductor systems of telegraphy and telephony will be allowed to die. The astonishing thing is that, even in the days of radio's greatest limitations, anyone ever thought it necessary to embellish the facts.

The potentialities of short-wave radio appear to be very great in a limited sphere. In the autumn of **1918**, the author proposed to the British Air Board that the ignition systems of aircraft should be used for purposes of telegraphic identification. To this end, every aircraft was to have a three or four-letter identification signal—like a ship—and be provided with a rotable code-wheel in series with the engine ignition system. This code-wheel would have appropriate conducting and insulating segments, and would be normally short-circuited. Upon receipt of a pre-arranged signal from below—preferably a visible signal—the airman would rotate his code-wheel and thereby signal his identity in two ways; namely, by Hertzian, and air, or sound, waves. This matter is brought to mind now by a perusal of C. S. Franklin's report on his experiments with short waves, in which he states that the interference he experienced emanated mainly from the ignition systems of motor-boats and motor-cars (7*c*).

It is suggested that by the use of very short waves it may be possible for a ship to discover its distance from a signal source, because of the great consistency of the attenuation of these waves over sea. It is not recorded that experiments have been made with a view to discovering whether or not this attenuation varies with sunlight conditions, although it is known that there is a very great difference between the daylight and dark attenuation of short waves of the order used in broadcasting.

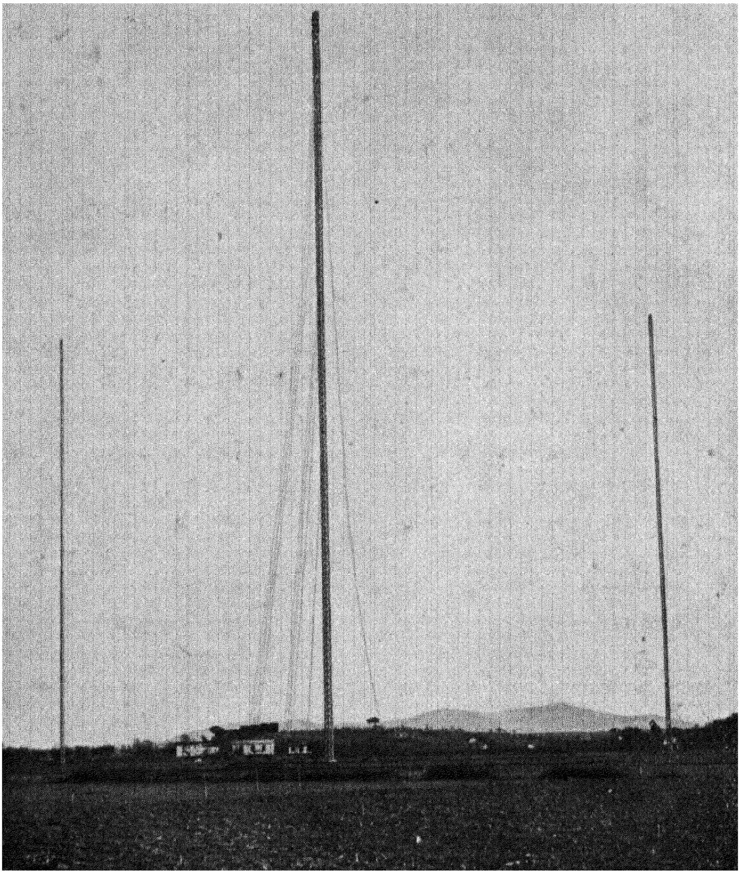
It has also been suggested recently that short-wave radio beams may be used between ship and ship as an aid-to-navigation in fog; and it is possible that with the instrumentalities now available, something along the lines proposed by A. N. Hovland to this end, in 1901, may be put into effect. (Br. Pat. 19,170/01.) (See also the following British Patent specifications: 15,569/03 Ladd; 19,878/06 De Forest; 27,938/06 De Forest; 18,632/12 Hienicke and Jasper.)

It has been shown that, in radio particularly, there is often a great distinction between an invention and the means to carry it out; and it is probably true that a number of inventions of great potential merit have gone into the discard, merely for the lack of means (instrumentalities) to put them into effect. We have seen what the triode has done for radio receivers, amplifiers, beam and other transmitters, and direction-finders. May it not be that it is capable of doing as much for some of the pre-radio systems of telegraphy without wires? If some of these systems could be resuscitated, they might now be used to supplant the present short-distance radio services, and so be the means of relieving the ether of its growing congestion on the shorter waves.[1]

[1] The following British patents have recently been issued on inductive systems incorporating the triode: 135,504, 151,530-1-2-7, to E. C. Hanson; 154,978, to Q. C. A. Craufurd and L. O. Doughty-Wylie; and 156,769, to E. C. Hanson (void).

There seems always to be a "Last West" beckoning the radio engineer with a taste and aptitude for pioneer work. It will certainly be a good thing when his technique is available to the healing profession, for it is doubtful that electro-cautery, electro-diathermy, and perhaps also radiography, have yet been developed to the limit of the possibilities attainable by the more general application of the triode, and fuller recourse to the data available in the radio research laboratory.

It may yet be possible to project vortex ethereal rings, and thereby secure some results not yet foreseen.



[To face page 75.

POULSEN ARC STATION AT ROME.

CHAPTER IV

THE POULSEN ARC[1]

By reason of its extreme simplicity, the Poulsen Arc still has a wide application as a generator of radio-frequency currents of high power and comparatively low frequency. Unfortunately, however, the radiations are encumbered with " mush " and harmonics, which must be eliminated if the arc is to be an important factor in the future.[2]

Here again, the invention was old before it found much application, but in this case the delay was probably due in large measure to the east wind of interested criticism.

The refinement of the Arc is very largely due to the energy and genius of C. F. Elwell (18), who, by the way, had the unique distinction, during the Great War, of being commissioned by the Italian Government to build a long-distance Poulsen station in the neighbourhood of Rome: a work that he carried out so successfully that he was made a Knight of Cross of the Crown of Italy. The Federal Telegraph Company of San Francisco are also responsible for much development and practical application of the Arc.

As late as December, 1921, the British Wireless Telegraphy Commission (26) recommended the installation of arcs in three of the stations of the proposed Imperial Chain: not because they were thought to be more efficient than the triode, but because of the advantage of their simplicity in view of the isolation of the proposed stations.

The Poulsen Arc began to attract serious attention in

[1] See Appendix, p. 180.

[2] Since the above was written, it is understood that great improvement has been effected by the British Post Office Engineers in the radiations of the Arc transmitter at Leafield. This has been done by screening the transmitter house and installing a " coupled circuit," which latter was part of Poulsen's original invention. (See Fig. 8 of his " British and American Specifications," and Fig. 10 herein.)

1912, when the Marconi Company issued the following circular, dated December 14th, 1912, to its stockholders:—

"Dear Sir (or Madam),—Mr. Marconi has recently returned to London, and has become acquainted with the statements which have been made in recent weeks and with the opinions which have been expressed that continuous waves would in future supersede the spark system.

"As these statements and opinions are liable to mislead shareholders and cause them some uneasiness, I am instructed to inform you that Mr. Marconi himself tested continuous wave systems many years ago, and experimented with them during the greater part of 1907 at the Poldhu Station. As a result of these experiments he learned the advantages and disadvantages pertaining to continuous waves, and eventually arrived at a compromise between the continuous waves and spark systems, combining the best points of both. This resulted in material changes in his system for long distance work, and new and important improvements were patented by him in 1907, which are mainly responsible for the progress since made in long distance wireless telegraphy.

"These inventions, which materially modify the spark system, seem to be surprisingly little known, notwithstanding the lectures delivered by Mr. Marconi at the Royal Institution of Great Britain on March 13th, 1908, and June 2nd, 1911, the Nobel Prize Lecture at Stockholm in 1909, and the address to the New York Electrical Society on the 17th of April, 1912, when he made statements relating to the use he was making of continuous waves, semi-continuous waves, and the elimination of the spark.

"By Order of the Board,

"(Signed) Henry W. Allen,

"*Secretary.*"

A few months after the date of this circular, the British Marconi Company increased its capital in order to acquire rights to the Goldschmidt Alternator, by means of which

a radio-telegraph service was established between Hanover in Germany and Tuckerton in the United States. Meantime, the merits of the Poulsen Arc, as compared with those of other generators then available, became more widely known and appreciated.

On May 7th, 1913, in his evidence before the British Select Committee (21), Mr. Marconi said: "It has been stated in evidence that my company recently endeavoured to purchase the Poulsen patents. I give an absolute denial to this statement. My company has had more than one opportunity of purchasing the Poulsen patents in years gone by, and it has not purchased them because, in my opinion, firstly, there was no advantage to my company to use the system; secondly, had there been, there has never been any reason why we should not have developed or used the system, for I believe it is not protected by any valid patent. In support of my opinion, the German Patent Courts, for which everybody who has to do with patents has the highest respect, has declared the Poulsen master patent to be invalid and has annulled the German patent" (21). On the same occasion, Mr. Marconi referred to a lecture by Professor Fleming before the Royal Institution on May 24th, 1907, wherein the Professor described an experiment which appeared to prove "incontestably" that the Poulsen Arc was not a generator of continuous waves.

In view of the foregoing, it is worthy of note that in 1920, the British Marconi Company having become financially interested in the Poulsen system, an unsuccessful attempt was made to get the British Patent thereon resuscitated and extended—it having expired about three years previously (9).

Also it is interesting to note that there are now seventy-eight stations equipped with Poulsen Arcs of 25 kW. and over (18).

CHAPTER V

BROADCASTING

> " And the night shall be filled with music,
> And the cares that infest the day
> Shall fold their tents, like the Arabs,
> And as silently steal away."
>
> —*Longfellow.*

THE paramount question of the moment is the control of broadcasting. There are the makings of a local broadcast receiver in almost any scrap heap; therefore there need be no limitation of the public enjoyment of the radio programme.

Anyone who has considered the almost complete prostitution of the cinema as an educational force, and its unhappy effect on the youth of to-day, cannot fail to appreciate the vital importance of directing to better ends the almost equally potent force of radio.

There are indications that radio's potentialities for insidious propaganda are already appreciated, and the only safe course seems to lie in Government control, particularly where there is representative democratic government, as in Great Britain and the United States. What could support this latter contention better than the fact that the British administration is even now engaged in an attempt to capture and broadcast the song of the nightingale?

To the slum child of to-day, the nightingale means about as much as the Phœnix, the Liver or the Dodo; but to-morrow he may be familiar not only with the songs of our birds, but, through a purged cinema, with their appearance and surroundings. If so, the next generation will undoubtedly be the better for it.

It cannot be too widely known that practically all the benefits of broadcast reception may be enjoyed by the use of equipment which need involve no patented invention,

and need cost no more than a few pounds; even when well made and attractively finished. It is only natural that companies, owning costly patents, should endeavour to cultivate a public demand for equipment involving their use, and which can be sold at less competitive prices; but the fact remains that perfect short-range reception is accomplished with the simplest apparatus.

There is, or should be, no serious disadvantage in being limited to the near-by station or stations; in fact the local programmes are increasingly liable to be of special local interest and may yet be indispensable. It is likely, therefore, that " Broadcatchers " of the future will settle themselves into two classes, which may respectively be termed " stunters " and " utilitarians." The former will demand equipment whereby they may attain the greatest distances, and will be less concerned with economy and simplicity; while the latter will want merely the most dependable and simple apparatus that will enable them to enjoy the local programmes. The former class will likely bear about the same numerical ratio to the latter, as do racing motorists to those who motor merely for purposes of transportation or pleasure.

If the foregoing premises are correct, there will be a large and increasing demand for simple, dependable, patent-free equipment. Such equipment should be designed to operate on a single-wire aerial of definite length, so that the purchaser is not required to experiment. Preferably, it should be fitted with a readily demountable " catwhiskerless " crystal detector, and a " variometer " tuning coil. The latter should be designed for minimum self-capacity, to which end it should preferably have a cylindrical stator. Such a set, with an aerial of reasonable elevation or clearance, should give dependable results up to six or eight miles from a broadcasting station, and permit of the use of several pairs of telephones. Moreover,

an audio-frequency amplifier could be added, should the user require more volume—say for a loud-speaker.

For slightly longer distances and greater selectivity, there should be a good market for a two-circuit "loose-coupler," with secondary calibrated in wave-lengths and preferably having both capacity and inductance variable. The reason for the latter is that it enables the ratio "capacity to inductance" to be varied to supply the most satisfactory signal voltage to the detector: but obviously the calibration would have to be predicated upon the fixed position of one of the variables. Provision could readily be made for the use of any type of detector, and for the addition of regeneration; and apart from the latter, no patent need be involved.

The effect that broadcasting may have upon the Press is still uncertain. It is claimed that since only the bare facts of the news may be broadcast, the effect will be to stimulate the demand for newspapers. The author was once discussing this question with two Canadian newspaper editors who held this view. By way of illustration, one said, "Suppose to-day the news is broadcast that so-and-so has been murdered," mentioning the name of a famous British politician then in office; whereupon, giving way to political prejudice, the other remarked, "and a nice day for it too." The first speaker went on to say that, in his opinion, everyone would want to buy to-morrow's paper to get the details, and he was probably right. It is certain that the broadcasting of parliamentary procedure will not find favour. To have to listen to it is one of the most trying ordeals of parliamentary life, and to do so gratuitously would be to throw away one's natural advantage; which reminds one of Gladstone's comment when he saw a Member of Parliament using an ear-trumpet.

The most inevitable benefit to be derived from broad-

casting, and one that is already making itself felt (particularly in Britain) is in the purification of our spoken language. In America, carrying and intelligible qualities seem often to be sought in announcer's elocution rather than general purity—so that the American air carries a variety of interpretations of our Mother tongue. It is not good that one's children should listen to an address on the "drayma," however well-informed it may be; and such a vagary is not explained by the contention that a certain kind of American English, differs from perfect English, only in that it is spoken through a different organ.

The author would give an earnest of his lack of prejudice in the matter by saying that he has the evidence of his own ears that, in 1924, at least one British "Uncle" disputed that there was no "k" sound in "indictment." Nevertheless, it has to be admitted that the beautiful articulation and usually perfect pronunciation of the officers of the British Broadcasting Company are tremendous educational factors, and one that must soon lead to the extermination of "Coolie" English.

Unquestionably there is much that Britain and America may learn from each other in the matter of broadcasting, and it is certain that it would be an advantage if "announcers" in North America were required to satisfy a central authority as to the purity and standard quality of their diction; as they do in Britain. This done, there would soon be no point in the announcement of the facetious German shopkeeper, "English spoken, American understood," and the New York Eastsider might learn to articulate an "r."

The following U.S. Patents are claimed, by those who are interested, to be more or less vital to an efficient broadcasting station in America:—

879532	Feb.	18,	1908,	De Forest
1129942	Mar.	2,	1915,	Arnold

1129943	Mar. 2,	1915,	Arnold
1137315	Apl. 27,	1915,	Heising
1201270	Oct. 17,	1916,	De Forest
1201272	Oct. 17,	1916,	De Forest
1218195	Mar. 6,	1917,	Logwood
1231764	July 3,	1917,	Lowenstein
Re. 14380	Oct. 23,	1917,	Colpitts
1314252	Aug. 26,	1919,	De Forest
1329283	Jan. 27,	1920,	Arnold
1349252	Aug. 10,	1920,	Arnold
1377405	May 10,	1921,	De Forest
1442146	Jan. 16,	1923,	Heising
1442147	Jan. 16,	1923,	Heising
1452032	Apl. 17,	1923,	Farrington

CHAPTER VI

REGENERATION: IN RECEPTION

In the experimental days of the triode, it was found that under certain conditions audio-frequency oscillations were set up, causing singing noises in the telephones. These noises would disappear (or their pitch would be varied) when the adjustments were altered; they were a nuisance and came to be known as the "Canaries." Their cause and its possible use, seem to have been discovered almost simultaneously by a number of persons, and thereafter it soon became apparent that a revolution was about to take place in the art of radio reception.

The singing was a manifestation of a property which was, in more or less degree, inherent in the triode, and which could be increased and brought under control for useful purposes by means which became the subject of numerous patents to different inventors in various countries. In some cases one use of the property was patented, and in other cases another. The consequence is that the patent situation on this feature is much involved; particularly in some countries.

In the United States of America, the first invention of the regenerative use of the triode was, until recently, credited to E. H. Armstrong,[1] who, according to Professor J. H. Morecroft, in the *Radio Broadcast* of August, 1922, having accidentally placed two coils "much nearer to each other than they should normally be," heard a strange noise in the telephones. This was a "beat" note, between the oscillation frequency set up by his triode or "audion" and that of an incoming signal which was being impressed on his aerial circuit. Thus was invented (if not for the first time) not only triode regeneration, but the detecting self-heterodyne: the simplest possible

[1] See Appendix, p. 160, U.S. Pat. 1,113,149; Br. Pats. 24,231/14 and 147,042.

instrumentality to reduce to practice the masterful invention of Fessenden.[1]

The *Year Book* for 1923, which is published by a Marconi subsidiary in London, credits the invention of the self-heterodyne to Meissner of Berlin in 1913, whereas it was specifically patented to H. J. Round in Britain by Patent No. 28,413 [2] of that year, and Meissner expressly disclaims it.[3] (Br. Pat. 252/14.) Nevertheless—and despite the further disclaimer of the British patented inventions of Franklin (13,636/13) and Armstrong (24,231/14)—Meissner's specification carries claims which appear to cover all three. If the reader is fond of mental exercise he will enjoy studying the latter (amended) specification in the light of the others mentioned therein.

The specification of Round's patent makes the following clear reference to the inherent capacity for regeneration in the triode: "By suitably adjusting the circuits, signals produced by continuous waves can be heard in the telephones. If the capacity between the grid and the third electrode is insufficient, a small condenser may be connected across the grid and the third electrode, or the oscillation circuit may be made to interact with the aerial or with an intermediate oscillation circuit by so arranging the circuits that there is mutual inductance between them."

Precisely the same circuit arrangement was previously patented in Britain to C. S. Franklin (13,636/13),[4] whose invention was the use of regeneration to nullify or reduce the resistance of the receiving system.

An important development of the regenerative principle in receivers, is the super-regenerative circuit, in connection with which the following patents and applications therefor are held to be more or less relevant: Br.

[1] See p. 33.
[2] See Appendix, p. 167.
[3] See p. 172.
[4] See Appendix, p. 158.

182,135, U.S. Serial 807,388 (?), Armstrong; Br. 156,330, U.S. 1,407,245, Bolitho; Br. 130,408, U.S. Serial (?) 276,856, February 13th, 1919, Turner.

Whether or not the U.S. Patent Office differentiates, or will differentiate, between the use of the "feed-back" circuit for the (*a*) generation of oscillations for transmission purposes, (*b*) generation of oscillations for "heterodyne" reception, and (*c*) amplifying received signals, the author does not know.

CHAPTER VII

THE TRIODE AS A GENERATOR OF RADIO FREQUENCY ALTERNATING CURRENT

By causing a telephone receiver to react on a telephone transmitter, A. S. Hibbard, in 1890, discovered the principle of the Hummer or Humming Telephone (Fig 27). Later, Professor Larsen, of Copenhagen, used the same principle in the production of alternating current from a direct current source (13). Therefore, the use of reaction or regeneration, in the production of alternating currents from a direct-current source, was well known when the triode came into being. Nevertheless, it is not recorded that anyone sought to duplicate the hummer phenomenon with the triode; which latter seems to have been accidentally developed as a generator, without reference to any prior art.

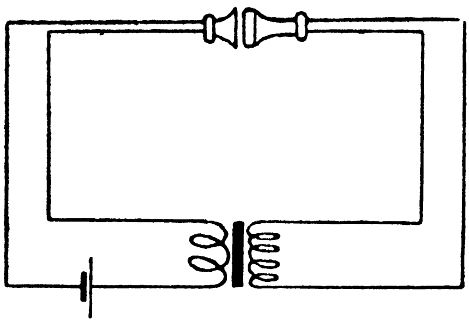


Fig. 27.
Telephone Hummer.

Since 1913 it appears to have been generally recognized that under certain conditions, which were only too easily established, the generating property of the triode was inherent and inevitable.

In Armstrong's (American) specification[1] we read: "It will be understood from what has been said that the ratio of transformation of the transformer should be adjusted to get the maximum signals without causing the audion to generate oscillations."

In the specification of his British Patent 13,636/13,[2] Franklin also directs attention to the danger of persistent oscillations being set up in the triode, and at about the

[1] See Appendix, p. 164. [2] See Appendix, p. 158.

same time De Forest, too, had mentioned the precautions necessary to prevent singing (11*b*).

The first reference in the records of the British Patent Office to the use of a triode as a useful generator for transmission purposes, seems to be in the specification of Br. Pat. 252/14 [1] to Von Arco and Meissner.

From the foregoing, it would appear that the possibility of generating radio-frequency alternating currents by means of a triode, was fairly well known for some time before anyone suspected that it could be developed for transmission purposes. The first to use the triode in a transmitter appear to have been Round in England, and Von Arco and Meissner in Germany; but such use does not appear to have been specifically patented anywhere,[2] unless, perhaps, in the latter country.[3]

[1] See Appendix, p. 168.
[2] See U.S. Application Serial No. (?) 52,176, September 23rd, 1915.
[3] Since the above was written, the first invention in America of the triode or audion as an oscillation generator has been credited to De Forest by a judgment of the U.S. Court of Appeals of the District of Columbia dated May 5th, 1924. (See p. 45.)

CHAPTER VIII

BEAM AND SHORT-WAVE RADIO

In an address to the shareholders of Marconi's Wireless Telegraph Company Limited, on December 3rd, 1923, Senator Guglielmo Marconi made the following statement in reference to beam signalling:—

"This system is, I believe, destined to bring about somewhat of a revolution in the methods hitherto employed for communicating by wireless with distant countries. According to this system the electric waves which carry the messages are projected and propagated in a beam in any desired direction only, instead of being allowed to spread around in all directions. The advantages of the new method are at least four-fold, because:

"1. Due to the better utilization and concentration of power a much smaller amount of electrical energy need be employed for a given distance, resulting in a substantial economy in capital and working expenses.

"2. Only stations inside a certain restricted angle or sector are enabled to receive, and this increases the privacy and secrecy of communication, besides greatly reducing the possibility of mutual interference with other stations.

"3. Owing to the employment of comparatively short waves, the speed of transmission and reception can be several times greater than what is attainable with existing long-distance systems.

"4. The disturbance caused by the effects of atmospheric electricity are greatly minimized.

"During the tests which I have already referred to, communication was successfully carried out on this system between England and many places abroad, including St. Vincent (Cape Verde Islands), up to a distance of 2,250 nautical miles, by the employment of only a fraction of the electrical energy hitherto found necessary to cover

such distances. I am now completing arrangements which will enable me to give this system a thorough test between England and the United States of America" (14).

A beam demonstration was given by C. S. Franklin before the Institution of Electrical Engineers, London, on the 3rd of May, 1922, and repeated by Senator Marconi in New York in the following June, arousing much popular interest. In the circumstances it will be appropriate here to review the history of this branch of the art.

It was by means of very short waves and parabolic reflectors that Hertz carried out his experiments and laid the foundation of radio; and it is recorded that he produced waves of 30 centimetres in length, which he concentrated into a single beam. It is also recorded that Senator Righi produced waves as short as 2·5 centimetres (1), while Senator Marconi used waves of ten inches in length in 1896-97.[1]

In Marconi's provisional specification of 2nd June, 1896, we read that when it is desired to transmit to the greatest possible distance and in only one direction, "I place the oscillation producer at the focus or focal line of a reflector directed to the receiving station, and I place the tube or imperfect contact at the receiving instrument in a similar reflector directed towards the transmitting instrument;" while in a Marconi (Canadian) prospectus (undated, but apparently published in 1907 [2]) we read:—

"Com. Marconi has recently perfected instruments by means of which he is enabled to so direct the waves of wireless that they will travel in a direct line from the point of transmission to the point of receipt, and cannot

[1] See Appendix, p. 120.
[2] Published over the name of "Munroe and Munroe, Agents for the Marconi Underwriters of America."

be received at any other station or point than the one at which they are intended to be received. By this means wireless waves are conducted through the ether in focal lines of force exactly as though wires were used.

"Recently a group of war vessels at anchor on the Mediterranean side of Gibraltar were employed in testing the new improvement.

"Marconi, from his station in Cornwall, was enabled to select one of these vessels, and by directing his waves upon that one vessel, just as a beam of light might be focussed upon a given point, was able to communicate with her without her sister ships being aware of the fact."

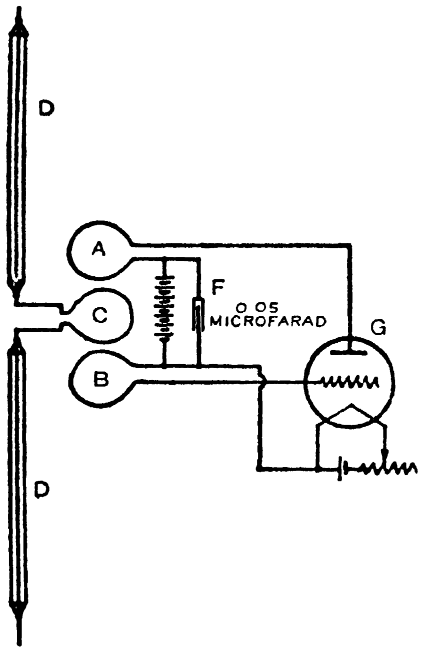


Fig. 28.
Hartley Circuit.
Circuit of 10-metre Generating Set.
(By courtesy, U.S. Bureau of Standards.)

The foregoing quotations tend to create the impression that the recent developments in "beam" radio represent merely the re-discovery of a lost art. As a matter of fact, the first relates to the reduction to practical use, by means of instrumentalities only recently available, of inventions and discoveries made some thirty years ago. Of the others, while perhaps they are all a little over optimistic, the last particularly serves to illustrate the temptation to "paint the (radio) lily" to which so many still succumb.

The practical utility of short-wave "beam" and, in greater degree, "broadcast" signalling, is now established; but on account of the attenuation of short waves

during sunlight, it has yet to be proved that they will be useful for continuous long-distance communication. Moreover, the known fluctuations of the apparent path of signal waves of the length now in use, suggest that beams will be impracticable for long-distance work, unless they are very little concentrated, and consequently not beams at all. It is possible, however, that very short waves may be found to be more persistent in their direction than the longer waves.

As to the prospect of energy economy, to which Senator Marconi refers, there can be no doubt as to the efficacy of short waves, *per se*. This has frequently been demonstrated during the last few years by the performances of amateurs. In fact, it is getting to be a commonplace thing, particularly in the winter months, for these enthusiasts to engage in two-way telegraph communication over distances of the order of two thousand miles, with only one hundred watts of energy. If they used "reflectors" their performances no doubt would be credited to the efficacy of the "beam."

Before any opinion can be expressed on the efficacy or practicability of the "beam" method, as such, over long distances, it must be demonstrated that, as compared with what can be accomplished on the same wave without a reflector, the beam method secures:—

(1) Useful economy of the ether.
(2) Useful secrecy.
(3) Any appreciably greater distance, and
(4) Any considerable economy of power.

The first alone will justify the method, if maintenance costs are not excessive.

There seems to be little likelihood of the second.

The third is important, and the fourth is likely to be negligible, except in so far as the operating speed may be governed by the power used.

Having regard to the power-economies which, as is well known, can be effected by the use of short waves, *per se*; and in view of operating costs and overhead charges which within certain limits are independent of power consumption, there appears to be little benefit to be derived, in terms of power-economy, from the use of reflectors; even when the latter are developed to perfection.

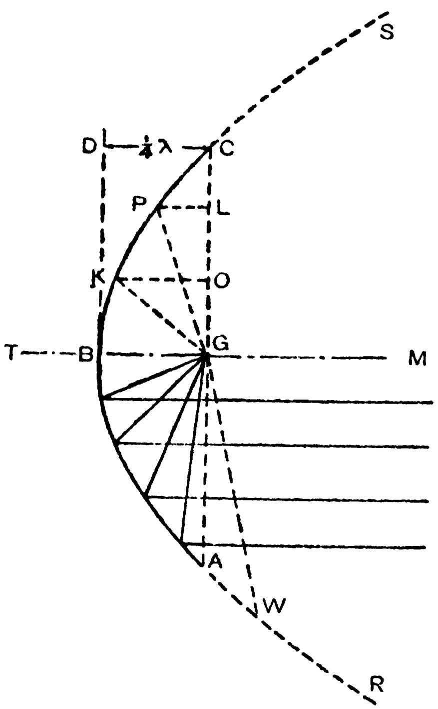


Fig. 29.
Illustrating the need of a wide aperture to obviate leakage as at GW.
Principle of reflection of waves from a parabolic reflector.
(By courtesy, U.S. Bureau of Standards.)

If, however, reflectors are evolved whereby radiation is limited to an angle of even 30°, their use will be amply justified, although no useful "secrecy" objective will be attained. In this connection it must not be overlooked that a 30° "beam" in trans-Atlantic communication would give a wave-front of approximately 1,500 miles at the receiving terminal. Even if reflectors prevent only rearward radiation—and this is theoretically possible by other methods—their use will be amply justified, since the major problem to-day is rather how to effect economies in the ether than in power-consumption.

The generation and radiation of power at very high frequencies present many difficulties, when twenty or thirty kilowatts have to be radiated; and herein lies the chief concern of technicians: moreover, when reflectors are used, the problem is further complicated.

Reference to Fig. 29 will show the importance of wide-aperture reflectors. For practical purposes Marconi proposes to use an aperture of eight wave lengths (10*d*), which, for the Canadian stations of the proposed Imperial Chain (29), will involve reflectors 840 metres wide, since the said stations are licensed for waves of from 85 to 105 metres (but with no angular limit, except that imposed by the British contract). On the other hand; in Marconi's Society of Arts paper (10*d*), there is reference to a new type of flat aerial and reflector invented by Franklin, which may indicate that the parabolic form of reflector is losing favour. The new type suggests the directional radiator patented (Br. 130,064; U.S. 1,360,167) to Alexanderson, who claims for it " a directive effect comparable with the focussing of a beam of light by a lens or mirror."

It is popularly believed that a radio beam has been successfully focussed on Sydney, Australia, from Poldhu, England, and this belief is no doubt due in some measure to the title of Marconi's recent paper, " Results obtained over very long distances by short wave directional wireless telegraphy, more generally referred to as the Beam System," in which communication with Australia was mentioned. The paper itself, however, makes it clear that this is not so; moreover, the efficacy of such focussing would need to be proved, not only at the objective, but at other points outside of the prescribed path of the beam, as is required, in fact, in the British contract (29).

The practicability and utility of the beam method of transmission and reception of waves of the order of ten metres in length appears to be unquestionable; but it is early yet to form an estimate of the distance that may be accomplished thereby (30). It has to be borne in mind that the shorter the wave the greater is the limitation upon the power that can be radiated : while the longer the wave the greater are the difficulties of reflection and

focus—until a parabolic reflector becomes out of the question.

A useful method of precise measurement of short waves has been evolved by the United States Bureau of Standards, and is described in a paper by F. W. Dunmore and F. H. Engel in the Proc. I.R.E. of October, 1923 (Vol. ii, pp. 467-478).

The higher telegraphic speeds that will be possible with short waves—as compared with those now in general use—will, of course, be largely facilitated by the comparative smallness of the power required: even more so than by the higher frequency.

It is necessary that there should now be an accepted scientific definition of a " Radio Beam "; otherwise it would be well to delete the term from our vocabulary. For the purpose of the proposed Imperial Chain, it is defined as having a width of 30°, outside of which the strength of the radiations must not exceed 5 per cent. of that at the axis (29).

The possibilities of infinitely short electro-magnetic waves have been demonstrated by the sun since the creation, and our attention was directed to them by Clerk Maxwell as long ago as 1867;[1] moreover, in 1892, Sir William Crookes foretold the use of longer—but still short —electro-magnetic waves, in focussed radio-telegraphy.[2] Therefore it appears to be reasonable to hope that, at last, the radio beam is to emerge from the stock-prospectus into the field of practical telegraphy.

[1] See p. 18. [2] See p. 22.

Some Patent Specifications Relating to Beam Radio

British

1896	12039[1, 2]	G. Marconi.
1899	14449	S. G. Brown.
1900	1555	E. G. Foresio.
	14558	G. F. R. Blochmann (use of lenses).
1901	11003	G. F. R. Blochmann and C. E. Bichel (use of lenses).
	19170	A. N. Hovland.
1903	15569	H. W. Ladd.
1906	19878	De Forest.
1912	18632	H. Heinicke and M. Jasper.
1916	105909[1]	G. Marconi (void) (reflector).
1917	128665[1]	C. S. Franklin and others (reflector).
	128673	C. S. Franklin and others (reception of short waves).
	128983	C. S. Franklin and others (generation of short waves).
	130064	E. F. W. Alexanderson (directional aerial).
1918	134246	C. S. Franklin (reception of short waves).

American

744897[1]	F. Braun (reflector).
748597[1]	De Forest (reflector).
1360167	E. F. W. Alexanderson (directional aerial).

[1] See Appendix.
[2] U.S. Pats. 586,193 and re-issue 11,913.

CHAPTER IX

CONCLUSION

A CONSIDERATION of the cases of Hughes in 1879 and Marconi in 1896 inevitably reminds one that "A prophet is not without honour, save in his own country." The appropriateness of the axiom is not affected by the fact that Marconi achieved fame in Italy; because he had first become famous in England.

It is to be regretted that someone did not give to Hughes the encouragement and facilities for practical experiment which, nearly twenty years later, the late Sir William Preece gave to Marconi; but it must not be overlooked that the need of a wireless telegraph system was probably not so urgently felt in 1879 as in 1896.

Prior to 1896, Preece had in operation a system of inductive wireless telegraphy, and it was just when he was smarting under the failure of this system to provide communication with the East Goodwin Lightship, that Marconi came to him with a letter of introduction from Mr. A. A. Campbell-Swinton. Both Lodge and Rutherford had already shown that wireless telegraphy was practicable, and by the same essential method that was used by Marconi; but apparently they did not see or were not interested in its commercial potentialities, or were too much engrossed in other activities to endeavour to exploit them. This circumstance has, no doubt, contributed to the fact that to-day the layman regards "Marconi" and "Wireless" (or "Radio") as interchangeable terms, while the credit that is due to Hughes, Lodge, Popoff, Braun, Fessenden, Stone and others, is in danger of being forgotten, except by technicians.

There may be much to be said in favour of a monopoly of a public utility; but if experience of radio teaches anything, it is that there should be no private monopoly of a public utility, which is based upon an undeveloped art.

In other words, it is obviously undesirable that a monopoly should be so constituted that it might be concerned to defeat or delay the adoption of any invention of merit. This fact emerges most strongly from British experience, and even the late Sir William Preece was concerned about it. In 1907, when asked did he think that the practical development of wireless telegraphy had been due to the Marconi Company, he replied: "Not so very much, Sir. I think myself if the Marconi Company, or Mr. Marconi himself, had never appeared upon the scene we should have had wireless telegraphy now." On the same occasion he also gave it as his opinion that "the whole effect of the operations of the Marconi Company has been to check and really stop the growth of wireless telegraphy as a convenience to navigators as well as a commercial undertaking" (16).

The American story is somewhat different. Despite the circus psychology and cavalier financing of its promoters, the United Wireless Telegraph Company (owning the De Forest patents) built up a very big business and applied radio to the public service to an extent yet unheard of in Europe; but by 1912 a situation had been created which enabled the British Marconi interests to purchase the assets of the company for $700,000·00—a condition of the purchase being that the United Wireless Telegraph Company should admit the validity of certain Marconi patents, which they did (23).

The assets of the United Wireless Telegraph Company—in so far as they related to the American Company's territory—and the American patents of Sir Oliver Lodge, were later sold to the American Marconi Company for $1,488,800·00 in stock of the latter Company at par.

In November, 1919, the American Marconi Company was absorbed into the Radio Corporation of America, which also acquired certain radio properties and rights

from the General Electric Company, The Western Electric Company, The American Telephone and Telegraph Company, The Westinghouse Electric and Manufacturing Company, The International Radio Telegraph Company, The United Fruit Company, and the Wireless Specialty Apparatus Company.

Since its inception as a public utility, there have been two, and only two, distinct waves of technical progress in radio. The first came with the development of the uses of the triode, and the Great War, when the art was relieved of the incubus of private monopoly; and the second came with the regular broadcasting of entertainment, which started in Canada early in 1920, and led to the placing of the development and manufacture of radio-equipment on a more competitive footing.

Obviously there is a need of some legal machinery or organization which, regardless of vested interests, will facilitate the adoption of inventions of merit and public utility, and ensure a fair reward to their authors.

In 1922 an " Australian Inventions Encouragement Board " was formed, " to stimulate and encourage the Inventive Spirit of the Nation." If such a Board were created in every country, and each affiliated with a common central Board, we might again enjoy a wave of inventive progress such as characterized the years 1914 to 1918, without having to wait for another Armageddon.

The story of radio points yet another moral, and it is that, regardless of prefix or suffix, Telephony is Telephony, and Telegraphy is Telegraphy.

Radio is already in service as supplementary and auxiliary to other forms of telephony, and its applications are extending. On the other hand—and with the exception of the British Post-Office-Telegraphs—the big telegraph organizations appear still to regard radio as a sort of poor and suspected relation, and to be content to

leave its exploitation to others. This attitude is no doubt nourished by the absurd claims of the stock-manipulators and their "ballyhoos," who have beset radio from its birth; but in view of the great progress made in the last few years, its continuance is likely to prove unprofitable, if not contrary to the public interest.

APPENDIX

THE following specifications of British and American patents, or extracts therefrom, describe the more important steps in the evolution of Radio. They are reproduced here by special permission kindly granted by the Commissioner of Patents, Washington, D.C., and the Controller of H.M. Stationery Office, London. The British specification of Marconi's 1896-7 invention is " out of print," but a full copy may be seen in Fahie's " History of Wireless Telegraphy " (1), from which are quoted the extracts of that specification which appear herein.

Copies of the specifications of American and British patents of invention may be procured respectively from " The Chief Clerk, Department of the Interior, United States Patent Office, Washington, D.C.," and " The Superintendent, Patent Office, Sale Branch, 25 Southampton Buildings, London, W.C.2." The price of the American is ten cents each, U.S. and Canadian postage free, and the price of the British is one shilling each, inland postage free.

UNITED STATES PATENT OFFICE

FERDINAND BRAUN, OF STRASSBURG, GERMANY

MEANS FOR DIRECTING ELECTRIC WAVES FOR USE IN WIRELESS TELEGRAPHY

SPECIFICATION (UNABRIDGED) FORMING PART OF LETTERS PATENT NO. 744,897, DATED NOVEMBER 24, 1903

Application filed February 19, 1902. *Serial No.* 94,729. (*No model.*)

To all whom it may concern:

Be it known that I, FERDINAND BRAUN, a subject of the Emperor of Germany, residing at Strassburg, Germany, (whose post-office address is No. 1 Universitätstrasse, Strassburg, Alsace, German Empire,) have invented new and useful Improvements in Means for Directing Electric Waves to be Used in Wireless Telegraphy, of which the following is a specification.

The present invention relates to reflectors adapted for use in connection with wireless telegraphy for the purpose of imparting to the electric waves a certain direction of propagation.

It consists principally in a metallic grating of parabolic or similar form constructed or arranged in a novel manner, hereinafter more fully described.

The invention is shown in the accompanying drawings, of which—

Fig. 1 is a diagrammatic view illustrating the theoretical physical principle. Fig. 2 is a section of the new reflector. Fig. 3 is a perspective view, while Fig. 4 represents an improvement of the reflector by means of deflectors.

It is well known in optics that series of luminous lines located in one plane and parallel to each other at equal distances apart and having the same phase and amplitude of oscillation will produce what is called in optical science a " wave front " which is a plane. These lines are indicated in Fig. 1 by points A^1 A^2 A^3 A^4, which represent sections of the luminous lines making up the wave front normal to the plane of the drawings. The same effect can also be obtained by the arrangement of a parabolic mirror. If, for instance, in Fig. 2 F is the luminous point and A^3 A^2 A^1 A^2 A^3 are parts of a parabolical mirror of cylindrical shape, W^1 W^2 will indicate the wave front which is a plane. This method may be employed for wireless telegraphy in the following manner: A series of parallel rods A^3 A^2 A^1 A^2 A^3 are arranged at equal distances from each other, so as to produce a cylindrical parabolical mirror in the form of a grating. Each rod is connected by a straight wire to a small ball F, set in the focus-line of the mirror. As shown in Fig. 3, two sets of rods are provided for, and between the two balls F F^1 set in the focus-line a spark is generated from time to time by a Ruhmkorff apparatus or an electrical static machine. (Not shown.) Now it will be evident that as all rods are excited from the same centre and as the phase difference of the

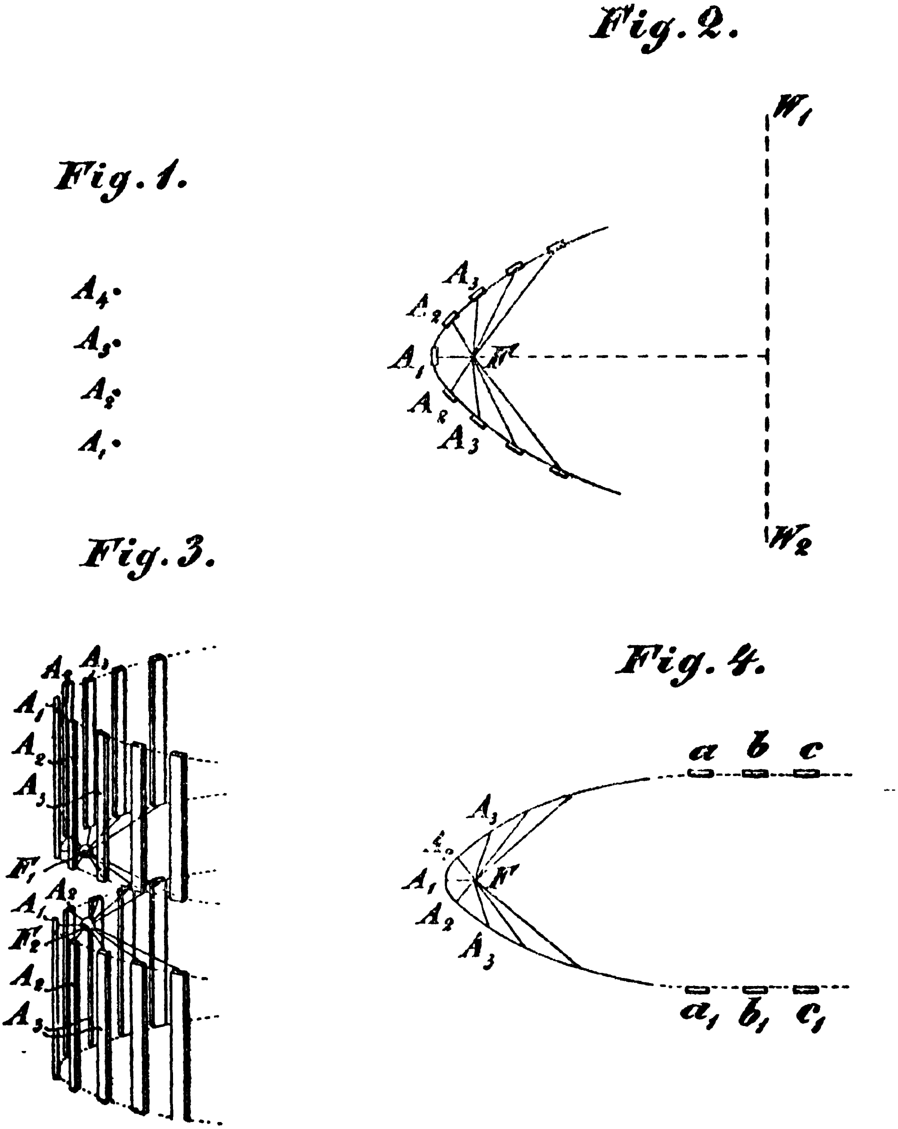


Fig. 1.
A4
A3
A2
A1
Fig. 2.
W1
A3
A2
A1
F
A2
A3
W2
Fig. 3.
A2 A3
A1
A2
A3
F1
A1 A2
F2
A2
A3
Fig. 4.
a b c
A3
A1
F
A2
A3
a1 b1 c1

Fig. 1.

oscillations of the single rods is determined by the length of the corresponding wires the set of rods act in such manner as to generate a wave front which must be in a plane. The wave motion therefore will be essentially rectilineal. It is obvious that by these means the greatest amount of the radiating energy will be guided in one direction. The phenomenon is physically analogous to the ordinary parabolic mirror and to Hertz's mirror for electric waves. Its peculiarity, however, is that every rod fulfils its own oscillation, provided it is tuned by ordinary means, as capacity and self-induction, to the same periodicity.

The advantage of the new system over the ordinary metallic continuous parabolic mirror is that much more energy is set in action, as the energy depends on the capacity of the single rods, which may be increased by increasing the capacity of the rods and adding, for instance, condensers to the same. A further advantage may be secured by suitable additional rods *a b c*, Fig. 4, or similar bodies—as, for instance, human bodies. These bodies act to prevent lateral deflection.

What I claim, and desire to secure by Letters Patent of the United States, is—

1. In mirrors for wireless telegraphy the combination of sets of rods tuned to the same frequency arranged parallel to each other in a parabolic cylindrical surface, spark-balls for electric disruptive discharge, and wires connecting the balls and the said rods, substantially as and for the purpose described.

2. In mirrors for wireless telegraphy, the combination of sets of rods tuned to the same frequency arranged parallel to each other in a parabolic cylindrical surface, and spark-balls for electric disruptive discharge, said balls being arranged in the centre line of the parabolic cylindrical surface, as set forth.

3. In mirrors for wireless telegraphy, the combination of sets of rods tuned to the same frequency arranged parallel to each other in a parabolic cylindrical surface, spark-balls for electric disruptive discharge, said balls being arranged in the centre line of the parabolic cylindrical surface, wires connecting the balls and said rods, and deflecting rods arranged parallel to the said centre line, substantially as and for the purpose described.

In testimony whereof I have hereunto set my hand in presence of two subscribing witnesses.

FERDINAND BRAUN.

Witnesses:

MATHIAS CANTOR,
MARIA SCHORN.

UNITED STATES PATENT OFFICE

LEE DE FOREST, OF NEW YORK, N. Y.

Wireless Signalling Device

SPECIFICATION (UNABRIDGED) FORMING PART OF LETTERS PATENT NO. 748,597, DATED JANUARY 5, 1904

Application filed December 24, 1902. *Serial No.* 136,435. (*No model.*)

To all whom it may concern:

Be it known that I, Lee de Forest, a citizen of the United States, and a resident of the city of New York, borough of Manhattan, in the county and State of New York, have invented certain new and useful Improvements in Wireless Signalling Devices, of which the following is a specification.

My invention relates to an improvement in devices for use in wireless signalling by which the radiated energy may be concentrated in the direction desired, one feature thereof involving the use of a reflector of the waves and another feature involving the use of horizontal directive and concentrating conductors.

My invention comprises the novel features and parts and combinations thereof, which will be hereinafter described, and particularly pointed out in the claims.

Fig. 1 represents in perspective a reflector of a peculiar construction. Fig. 2 shows in perspective another form of apparatus involving my invention. Fig. 3 shows in plan the same form as shown in Fig. 2 except that lag or impedance coils are employed to enable the antenna being placed near the reflector. Fig. 4 shows in perspective a further modification, and Figs. 5 and 6 are respectively plan and elevation of a modified construction.

It has heretofore been proposed to use a reflector for the waves radiated from a sending-conductor or antenna, the same to consist of a series of upright conductors which are disposed about the radiating-antenna in a curved line, more or less corresponding with a segment of a circle. So far as I am aware the conductors forming such a reflector have been insulated or not grounded.

In accordance with my present invention I surround the radiating-antenna A with a series of vertical conductors a, which may be called "secondary" antennæ, said conductors being disposed about the antenna A in a curve, which theoretically should be a parabola having its focus in the antenna A. This theoretical construction may, however, be departed from by means hereinafter explained. The conductors forming the reflector are, however, each grounded, either as in Fig. 1 by a direct ground connection E^1 or, as is shown in the other figures, by a conductor B, which extends horizontally in the direction it is desired to transmit the signals and is there connected with a ground E through a secondary spark gap or

gaps S^1. A spark gap S is placed at the base of the antenna A, which may be charged by any suitable apparatus, a coil G, battery H, and key I being herein shown for this purpose.

In the form of my device shown in Figs. 2 and 3 the vertical conductors *a*, forming the reflector, each have their base connected with the antenna A by a conductor D and are also each connected with a conductor B, extending horizontally in the direction it is desired to transmit the signal. These horizontal conductors are each grounded at their outer ends through a secondary spark gap S^1. This ground connection should be removed from the antenna a distance corresponding to a multiple of a quarter-wave length, preferably a half-wave length. The secondary radiating-antennæ *a*, forming the reflector, should preferably be located at such a distance from the main or primary antenna A that the waves radiated therefrom and travelling in the direction of the conductors B will be in step or phase with that part of the wave radiating from the primary antenna A, which is travelling in the same direction. To secure this, the length of the conductors connecting each of the reflecting or secondary antennæ *a* with the main antenna A added to the length of the conductors B, connected thereto, should be equal to a half-wave length more than the length of the conductor B, which is connected with the antenna A. As it would in most instances be undesirable to separate the primary and secondary antennæ to such a distance, the same result is obtained by interposing lag producing or retarding devices in the conductors D, connecting the bases of antenna A and reflectors *a*—such, for instance, as the inductance-coils C. (Shown in Figs. 3 and 4.) The actual length of the conductors B may also be reduced by inserting therein impedance-coils or other lag producing devices after the manner usual when such a result is desired.

In Fig. 4 a modification is shown in which the conductors B are replaced by a sheet of conducting material covering substantially the same area as the conductors B.

Fig. 5 shows in plan, and Fig. 6 in elevation, a construction which in the main is like that shown in Figs. 2 and 3. One structural difficulty attendant upon the use of the reflecting-conductors is that their supports present so much surface to the wind and in such an unsupported form that they are liable to be blown down. To remedy this, I prefer to continue the supporting structure until its ends meet, thus forming a complete inclosure, which would most naturally be of a circular shape or approximating thereto. This structure except for the reflecting-conductors or secondary antennæ should be of such material as will not seriously interfere with the free passage of the electric waves—such, for instance, as wood. Such a structure is shown at F in Figs. 5 and 6. I thus complete the curved form of the reflector and strengthen it, so as to enable it to better resist the wind-pressure and in addition do away with the exposed concave side which catches the wind. Being of wood it offers no obstacle to the passage of the waves. The horizontal conductors B or B^1, extending outward from the base of the antennæ, co-operate with the antenna A and the

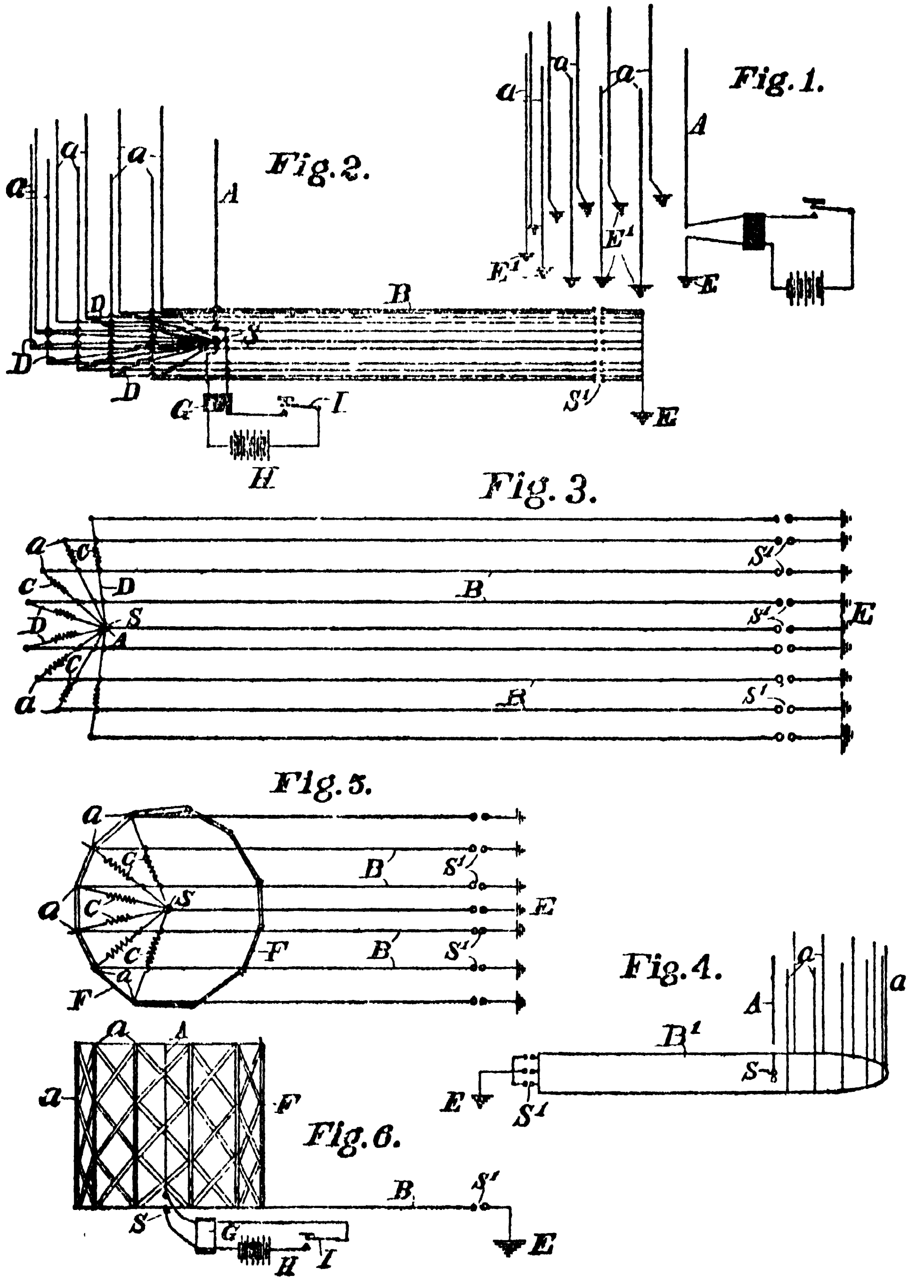


Fig. II.

reflector-conductors or secondary antennæ *a* to give a directional effect to the waves, whereby a much larger percentage than usual of the electrical energy is directed along the plane of said conductors and being once directed along this plane continues in that direction. I am thereby enabled to secure a greater range and effect with a given power.

The above feature is in addition to the reflection caused by the conductors *a* and would occur if the conductors *a* were omitted. This action is fully set forth and generically claimed in a divisional application for patent filed by me December 8, 1902, Serial No. 134,312, and is not, therefore, herein broadly or separately claimed.

Having thus described my invention, what I claim, and desire to secure by Letters Patent, is—

1. In wireless signalling, the combination with an antenna and means for communicating electric oscillations thereto, of a reflector for said oscillations and a ground connection therefor containing a horizontal conductor extending in the direction in which the waves are reflected.

2. In wireless signalling, the combination with an antenna and means for communicating electric oscillations thereto, of a reflector for said oscillations and a ground connection therefor containing a horizontal conductor extending a half-wave length beyond the antenna in the direction in which the waves are reflected.

3. In wireless signalling, the combination with an antenna and means for communicating electric oscillations thereto, of a reflector comprising vertical conductors which are connected with the base of the antenna and a conductor connected with the base of each of said reflector-conductors and extending in the direction in which the waves are reflected and a ground connection therefor located a half-wave length beyond the antenna.

4. In wireless signalling, the combination with an antenna and means for communicating electric oscillations thereto, of a series of vertical conductors forming secondary antennæ disposed about one side of the primary antenna to form a reflector, a conductor connecting each conductor of the reflector with the primary antenna, a horizontal conductor extending from the base of each secondary antenna in the direction in which the waves are reflected, a ground connection for said horizontal conductors located at a multiple of a quarter-wave length from the primary antenna, the length of the connection between the base of the primary antenna and points in the horizontal conductors abreast of the primary antenna being equivalent to a half-wave length.

5. In wireless signalling, the combination with a radiating-conductor and means for communicating electric oscillations thereto of a reflector for said waves connected with the said wave-radiating conductor, said connections containing lag-producing devices adapted to cause the reflected waves to coincide in phase with the waves directly radiated from the radiating-conductor and travelling in the same direction.

In testimony whereof I have hereunto affixed my signature, this 17th day of December, 1902, in the presence of two witnesses.

LEE DE FOREST.

Witnesses:
H. L. Reynolds,
Ernest Knight Satterlee.

SPECIFICATION OF BR. PAT. NO. 105,909 (VOID)

Convention Date (Italy), March 28, 1916
Application Date (in the United Kingdom), March 27, 1917.
No. 4427/17
Complete not accepted

COMPLETE SPECIFICATION

Improvements in Wireless Telegraphy and Telephony

I, Guglielmo Marconi, G.C.V.O., of Marconi House, Strand, London, W.C.2, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to an improvement in wireless telegraphy and telephony and is based on reflection phenomena; by means of it the waves can be directed and confined to a predetermined direction and reception can also be limited to waves proceeding from one direction.

The advantages achieved are as follows:—

1. Greater range of transmission.
2. Greater freedom from interference between stations working in the vicinity of each other.
3. The possibility of accurately determining the direction in which a transmitting station lies.
4. A lessening of all disturbances caused by the natural electrical perturbations of the atmosphere.

According to this invention there is arranged about the usual antenna of the transmitting or receiving station, a number of parallel antennæ which lie in a parabola of which the focus is the transmitting or receiving antenna. These antennæ are tuned to the length of the waves to be transmitted or received. These additional antennæ act as reflectors of the waves which are thus transmitted and received in the direction of the axis of the parabola, and when two stations communicate with one another the axes of their reflecting parabolas should be coincident.

The invention is illustrated by the accompanying drawing,[1] in

[1] P. 111.

which Fig. 1 shows sending and receiving stations, while Fig. 2 shows a modification.

In Fig. 1, A is a transmitting station and B a receiving station. *a* is the generator, *b* the receiver and *c* are the reflecting antennæ.

In the form shown in Fig. 2, the reflecting antennæ consist of wires *e* which have inductances inserted in them for the purpose of tuning and are suspended from a frame *d* supported by guys *f*.

The antennæ may be earthed or not.

The apertures of the parabolas should be as large as is practically possible and preferably not less than the length of the waves employed.

The focal distance of the parabola should be preferably of the order of $\frac{1}{4}$, $\frac{3}{4}$, $\frac{5}{4}$, etc., of the wave length employed. The antennæ of a reflector system may be placed at a distance from each other equal to $\frac{1}{10}$ of their height. Reflection will be more complete the greater the number of the antennæ.

The antennæ of the reflector system may be syntonized by the ordinary methods; i.e., by the employment of suitable and adjustable inductances or condensers.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

In radio-telegraphy or radio-telephony, a number of syntonized antennæ arranged in a parabola about the transmitting or receiving antenna at the focus.

Dated this 27th day of March, 1917.

CARPMAELS & RANSFORD,
Agents for Applicant,
24 Southampton Buildings, London, W.C.2.

SPECIFICATION OF BR. PAT. NO. 128,665

Application Date, August 29, 1917. *No.* 12,441/17
Complete Left, March 26, 1918
Complete Accepted, July 3, 1919

COMPLETE SPECIFICATION (UNABRIDGED)

Improvements in Reflectors for use in Wireless Telegraphy and Telephony

We, Marconi's Wireless Telegraph Company, Limited, and Charles Samuel Franklin, Electrical Engineers, both of Marconi House, Strand, London, W.C.2, do hereby declare the nature of this invention (in part a communication from Guglielmo Marconi, G.C.V.O., D.Sc., at present at the Hotel Excelsior, Rome,

Fig.1.

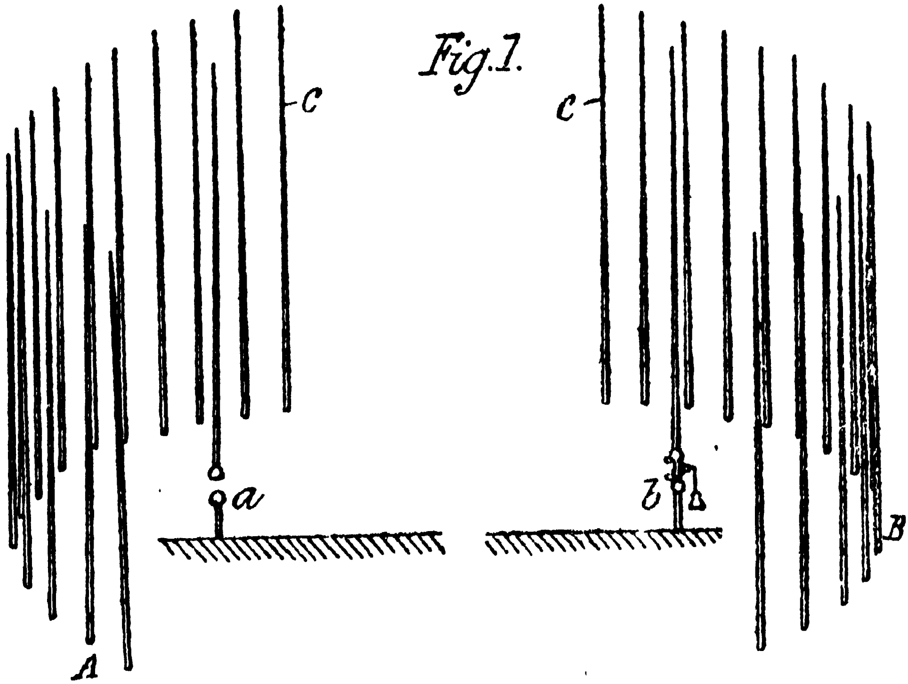


Fig.2.

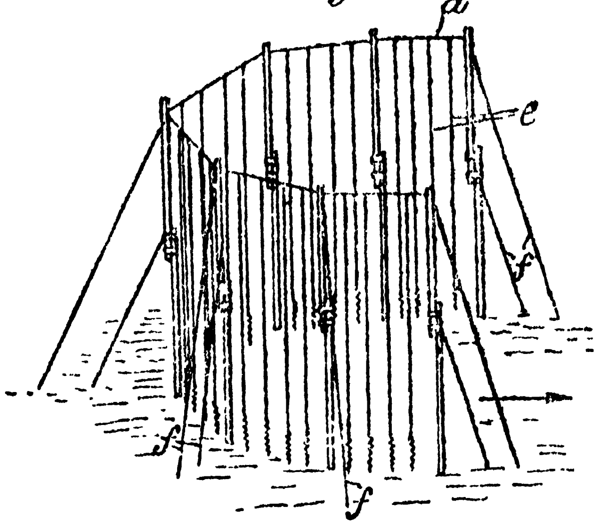


Fig. III. Marconi's British Patent 105,909 (Void). See pp. 109-110.

Italy), and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to improvements in the use of reflectors for transmitters and receivers in wireless telegraphy and telephony.

The use of a reflector for directing the energy of a wireless transmitter in any desired direction has been many times suggested. The advantages to be expected from thus directing the energy in the desired direction (such as increase of range, avoidance of interference of all kinds, and comparative secrecy) are so great, that it is rather surprising that since the early work of Hertz and Marconi no practical results have been obtained by the use of reflectors.

Hertz showed that by placing an oscillator in the focus of a reflector bent in the form of a cylindrical parabola, the energy was directed sensibly in one direction.

In 1896 Marconi, using his improved coherer, obtained a range of about three miles with an oscillator placed at the focus of a reflector, and the receiving conductor also placed at the focus of a reflector.

In 1901, Braun took out Patents in Germany Nos. 146,302 and 146,303, with a corresponding Patent in America No. 744,897,[1] for a reflector made of two series of parallel rods arranged above each other and in the form of a cylindrical parabolic mirror. The nearer ends of the two sets of rods were connected by means of wires to spark-balls, placed in the focus of the mirror. It is stated in the American patent that " it will be evident that as all the rods are excited from the same centre and as the phase difference of the oscillations of the single rods is determined by the length of the corresponding wires, the sets of rods act in such a manner as to generate a wave front which must be in a plane. The wave front therefore will be essentially rectilineal." In fact, the construction described simply gives a Hertz oscillator of a peculiar shape which has a wave length much longer than the natural wave length of the separate rods, and which has practically no directional properties.

In 1902, De Forest applied for a patent in America (granted in 1904 under No. 748,597)[2] describing a reflecting system in combination with a series of wires extending in the direction in which it is desired to send the energy and which, it is alleged, helps concentration in this direction. Fig. 1 of the drawings shows a system comprising a vertical aerial placed at the focus of a reflecting system consisting of a number of vertical aerials disposed in a parabolic curve, all the aerials being grounded. The inventor states that he believes the grounding of all the aerials to be novel and describes means for increasing the concentration in the desired direction by horizontal wires disposed in various ways.

A reflecting system comprising a number of wires or rods disposed as a cylindrical parabola and all tuned to the same wave

[1] See p. 102 [2] See p. 105.

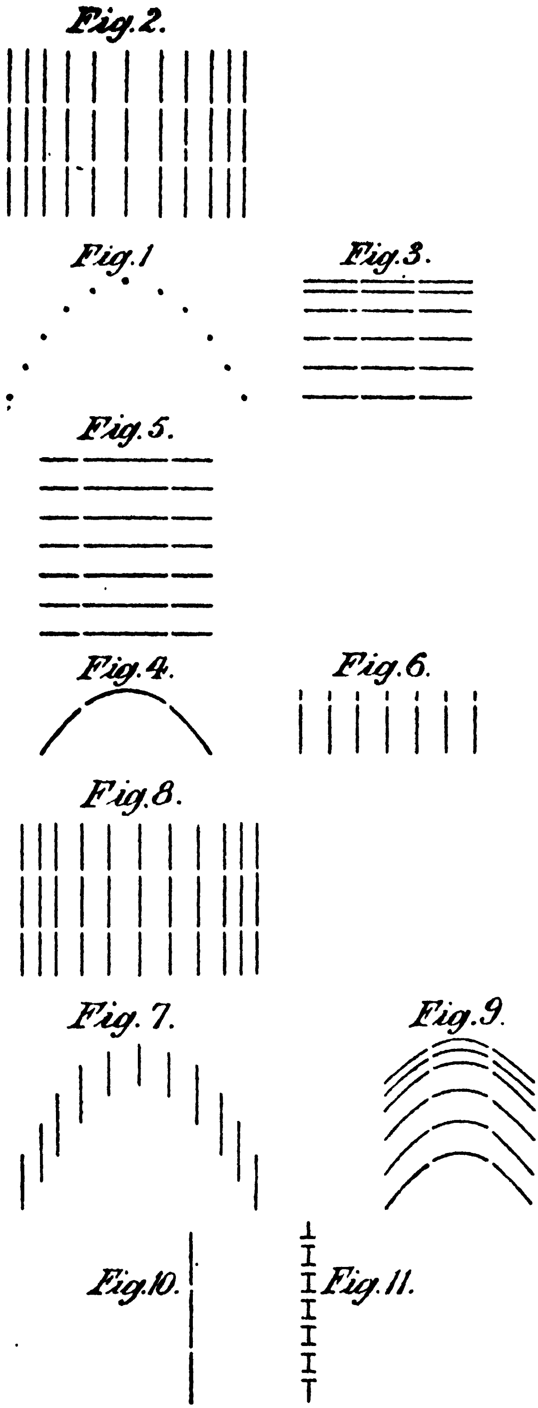


Fig. IV.

length as that of a transmitter placed at the focus thereof is accordingly not novel, while it is also known that in order that the reflected waves and the direct waves should unite their effects in the desired direction, the focal length of the reflector should be one, three, or an odd multiple of a quarter wave length. Such a system gives a certain amount of concentration in the desired direction, and we have found that this is strongest if the focal length is one-quarter wave length, weaker if the focal length is three-quarter wave length, and hardly appreciable if the focal length is five-quarter wave length or more. At best, with this simple system about 80% is the maximum increase in range hitherto obtained when using such reflectors both at the transmitting and receiving ends.

According to this invention, we construct a reflector of two or more sets of rods (which term includes strips and wires) arranged on a parabolic surface around the transmitting or receiving aerial as a focus, each rod being tuned to the aerial and the rods of the different sets being preferably in line with each other. By this means we are enabled to increase very largely the efficiency and effect of the reflector; for example, by making the reflector of three sets of rods arranged on a parabolic surface and having a focal distance of one-quarter wave length, we can increase the range from 400% to 500% as against 80% obtained with the simple reflectors before known.

The reflector may be described in other words as follows:—

On a parabolic surface surrounding a transmitter or receiver and in the correct direction having regard to the polarization of the transmitted waves, is arranged a number of long wires which are divided up into elements each in tune with the transmitter. The length of each element is preferably about half a wave length, but may be made either greater or less than this by inserting in it either a condenser or an inductance. The adjacent ends of these elements may be insulated from each other, or joined by inductance coils or condensers, the controlling factor being that each element when in its working position in the reflector, is in tune with the aerial.

In practice we find that some of the elements may be removed slightly from the true parabolic surface provided that those elements of the reflector which are nearer the focus than they would be if on the parabolic surface are tuned to a rather longer wave, and those elements which are farther to a rather shorter wave.

For very short waves no earth connections are required or desirable, but for longer waves it is an advantage to earth the aerial and the lower elements of the reflector.

Very good results can be obtained by arranging the elements on a cylindrical parabolic surface, but better results can be obtained by arranging them on a true paraboloid, particularly when using a reflector having a focal length equal to three-quarter wave length or more.

Our invention is illustrated by the accompanying drawings. Fig. 1 is a plan, Fig. 2 a rear view and Fig. 3 a side view of a reflector constructed in accordance with this invention and having three sets

of parallel rods arranged on a cylindrical parabolic surface; this arrangement is for concentrating vertically polarized waves in the horizontal direction. Figs. 4, 5 and 6 are similar views of an arrangement for concentrating horizontally polarized waves in the horizontal direction. Figs. 7, 8 and 9 are similar views of a reflector having three sets of parallel rods arranged on a true paraboloid instead of a cylindrical parabola; this will concentrate both vertically and horizontally polarized waves in the horizontal direction.

These figures illustrate reflectors made with three sets of parallel rods, or, stated otherwise, reflectors made up of a number of wires each divided into three elements, each element being in tune with the transmitted or received wave. As illustrated, each of these elements should be nearly half a wave length long; alternatively each of these wires may be divided up into a larger number of elements connected together by condensers.

Fig. 10 shows one wire divided into three elements each in tune with the desired wave.

Fig. 11 shows one wire divided into a number of shorter elements connected together by condensers. The capacity of each condenser must be such that if joined in circuit with the inductance of the wire joining it to the next condenser it would form a circuit in tune with the desired wave.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. In wireless telegraphy, a reflector consisting of two or more sets of rods arranged on a parabolic surface around a transmitting or receiving aerial as a focus, each rod being in tune with the aerial, substantially as described.

2. A modification of the reflector claimed in Claim 1, in which some of the elements are slightly removed from the parabolic surface, those which are brought nearer to the aerial being tuned to a longer wave and those which are removed further from it being tuned to a shorter wave.

Dated the 26th day of March, 1918.

CARPMAELS & RANSFORD,
Agents for Applicants,
24 Southampton Buildings, London, W.C.2.

EXTRACTS FROM THE SPECIFICATIONS OF BR. PAT. NO. 12,039/1896

Date of Application, 2nd *June*, 1896
Complete Specification Left, 2nd *March*, 1897
Accepted, 2nd *July*, 1897

PROVISIONAL SPECIFICATION

I, Guglielmo Marconi, of 71 Hereford Road, Bayswater, in the county of Middlesex, do hereby declare the nature of this invention to be as follows:—

According to this invention electrical actions or manifestations are transmitted through the air, earth or water by means of electric oscillations of high frequency.

. . . .

When transmitting through the air, and it is desired that the signal or electrical action should only be sent in one direction, or when it is necessary to transmit electrical effects to the greatest possible distance without wires, I place the oscillation producer at the focus or focal line of a reflector directed to the receiving station, and I place the tube or imperfect contact at the receiving instrument in a similar reflector directed towards the transmitting instrument.

When transmitting through the earth or water I connect one end of the tube or contact to earth and the other end to conductors or plates, preferably similar to each other, in the air and insulated from earth.

I find it also better to connect the tube or imperfect contact to the local circuit by means of thin wires or across two small coils of thin and insulated wire preferably containing an iron nucleus.

Dated this 2nd day of June, 1896.

GUGLIELMO MARCONI.

COMPLETE SPECIFICATION

My invention relates to the transmission of signals by means of electrical oscillations of high frequency, which are set up in space or in conductors.

In order that my specification may be understood . . . I will describe the simplest form of my invention by reference to Fig. 1. In this diagram A is the transmitting instrument and B is the receiving instrument, placed at say ½ mile apart.

. . . .

The arrangement A is commonly called a Hertz radiator, and the effects which propagate through space Hertzian rays. The receiving instrument B consists of a battery circuit J, which includes a battery or cell K, a receiving instrument L, and a tube T containing metallic powder or filings, each end of the column of filings being

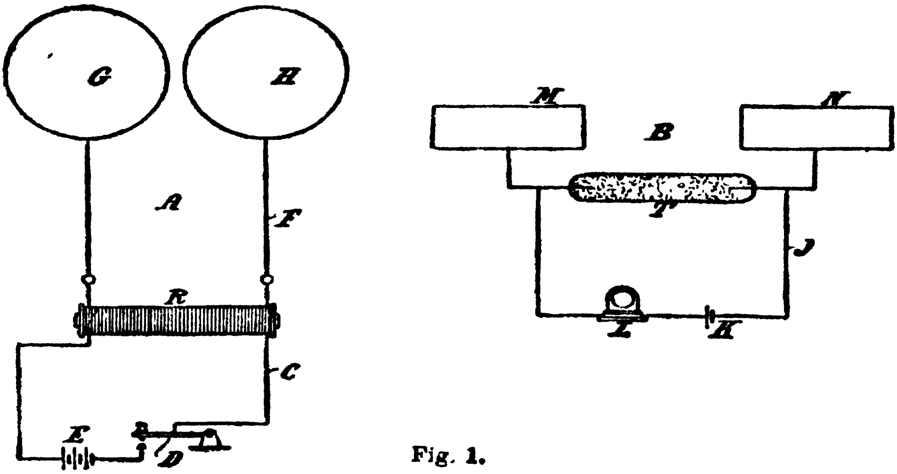


Fig. 1.

Fig. 2.

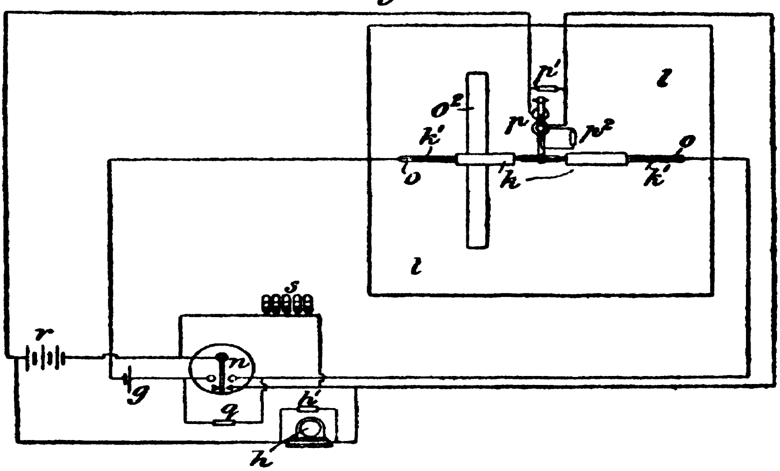


Fig. V.

also connected to plates or conductors M N of suitable size, so as to be preferably tuned with the length of wave of the radiation emitted from the transmitting instruments.

The tube containing the filings may be replaced by an imperfect electrical contact, such as two unpolished pieces of metal in light contact, or coherer, etc.

. . . .

Fig. 4 is a vertical section of the radiator or oscillation producer mounted in the focal line of a cylindrical parabolic reflector *f* in which a side view of the spheres *e e* of Fig. 3 is given.

. . . .

My invention relates in great measure to the manner in which the above apparatus is made and connected together. With some of these forms I am able to obtain Morse signals, and to work ordinary telegraphic instruments and other apparatus; and with modifications of the above apparatus it is possible to transmit signals not only through comparatively small obstacles such as brick walls, trees, etc., but also through or across masses of metal, or hills, or mountains, which may intervene between the transmitting and receiving instruments.

I will first describe my improvements which are applicable to the receiving instruments.

My first improvement consists in automatically tapping or disturbing the powder in the sensitive tube. . . .

A further improvement consists in the mode of construction of the sensitive tube.

. . . .

In order to increase the distance at which the receiver can be actuated by the radiation from the transmitter, I place the receiver (i.e., the sensitive tube and plates) in the focal line of a cylindrical parabolic reflector *l* (Fig. 2), preferably of copper, and directed towards the transmitting station.

. . . .

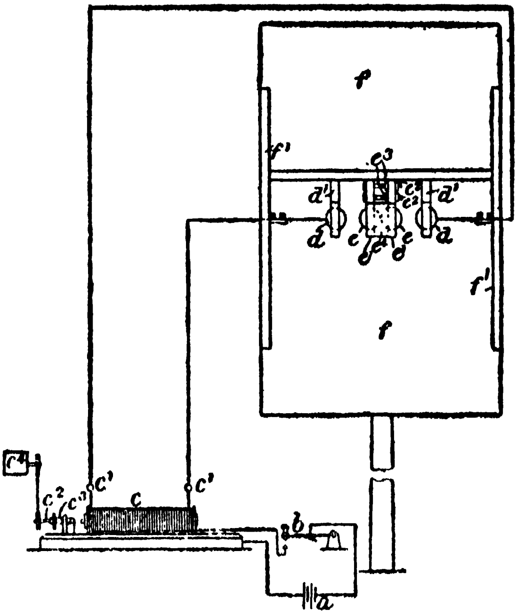
The reflector *l* (Fig. 2) should be preferably in length and opening not less than double the length of wave emitted from the transmitting instrument.

It is slightly advantageous for the focal distance of the reflector to be equal to one-fourth or three-fourths of the wave-length of the oscillation transmitted. . . .

A further improvement has for its object to prevent the electrical disturbances which are set up by the trembler and other apparatus in proximity or in circuit with the tube from themselves restoring the conductivity of the sensitive tube immediately after the trembler has destroyed it, as has been described.

. . . .

Another improvement consists in a modified form of the plates connected to the sensitive tube, in order to make it possible to mount the receiver in an ordinary circular parabolic reflector. This part of my invention is illustrated in Fig. 8, in which *l* is an ordinary



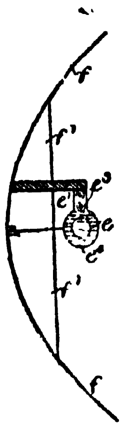


Fig. 4.

Fig. 3.

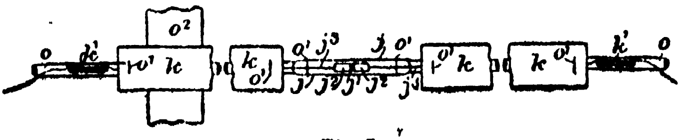


Fig. 5.

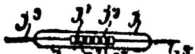


Fig. 6a.

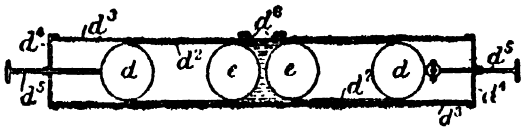


Fig. 6.

Fig. Va.

concave reflector. In this case the plates *k k* are curved and connected at one end to the sensitive tube *j*, and at the other to a small condenser formed by two metallic plates *k*2 of about one inch square or more, facing each other with a very thin piece of insulating material *k*3 between them. *p* is the trembler. The condenser may be omitted without much altering the effects obtainable.

. . . .

The receiver should be put in such a position as to intercept the reflected ring of radiations which exists behind or before the focus of the reflector, and ought to be preferably tuned with the length of wave of the oscillation transmitted. . . .

I will now describe my improvements which are applicable to the transmitting instruments.

My first improvement consists in employing four spheres for producing the electric oscillations.

. . . .

When it is desired that the signal should only be sent in one direction, I place the oscillation producer in the focus or focal line of a reflector directed to the receiving station. *f* (Fig. 3) and *f* (Fig. 4) show the cylindrical parabolic reflector made by bending a metallic sheet, preferably of brass or copper to form, and fixing it to metallic or wooden ribs *f l* (Fig. 3). Other conditions being equal, the larger the balls the greater is the distance at which it is possible to communicate. I have generally used balls of solid brass of 4 inches diameter, giving oscillations of 10 inches length of wave. . . .

Preferably the reflector applied to the transmitter ought to be in length and opening the double at least of the length of the wave emitted from the oscillator.

If these conditions are satisfied, and with a suitable receiver, a transmitter furnished with spheres of 4 inches diameter connected to an induction coil giving a 10-inch spark will transmit signals to two miles or more.

. . . .

A further improvement consists in causing one of the contacts of the vibrating brake applied to the induction coil to revolve rapidly.

. . . .

A further improvement has for its object to facilitate the focussing of the electric rays. This part of my invention is illustrated in Fig. 7, in which a view is given of the modified oscillation producer mounted in the focus of an ordinary parabolic reflector *f*.

. . . .

It is not essential to have a reflector at the transmitters and receivers, but in their absence the distance at which one can communicate is much smaller. Fig. 9 shows another modified form of transmitter with which one can transmit signals to considerable distances without using reflectors.

. . . .

I have observed that, other conditions being equal, the larger the

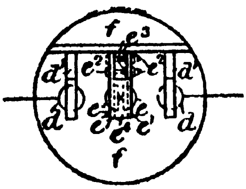


Fig. 7.

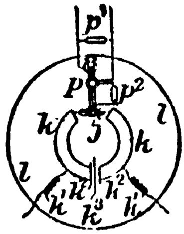


Fig. 8.

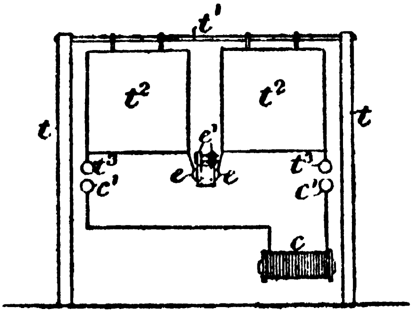


Fig. 9.

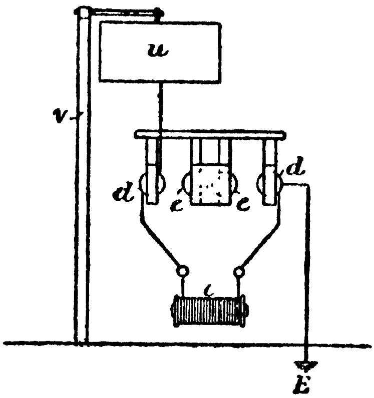


Fig. 10.

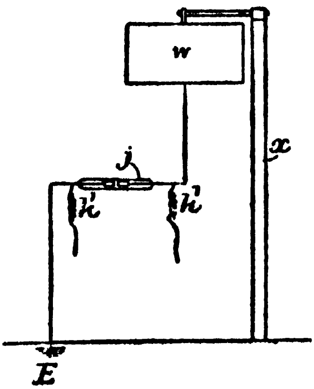


Fig. 11.

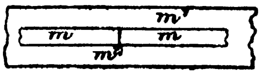


Fig. 12.

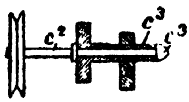


Fig. 13.

Fig. 14.

Fig V*b*.

plates at the transmitter and receiver, and the higher they are from earth, and to a certain extent the farther apart they are, the greater is the distance at which correspondence is possible.

. . . .

Where obstacles, such as many houses or a hill or mountains, intervene between the transmitter and the receiver, I have devised and adopt the arrangement shown in Figs. 10 and 11.

. . . .

At the receiver it is possible to pick up the oscillations from the earth or water without having the plate *w*. This may be done by connecting the terminals of the sensitive tube *j* to two earths, preferably at a certain distance from each other and in a line with the direction from which the oscillations are coming. These connections must not be entirely conductive, but must contain a condenser of suitable capacity, say of one square yard surface (paraffined paper as dielectric).

Balloons can also be used instead of plates on poles, provided they carry up a plate or are themselves made conductive by being covered with tinfoil. As the height to which they may be sent is great, the distance at which communication is possible becomes greatly multiplied. Kites may also be successfully employed if made conductive by means of tinfoil.

When working the described apparatus, it is necessary either that the local transmitter and receiver at each station should be at a considerable distance from each other, or that they should be screened from each other by metal plates. It is sufficient to have all the telegraph apparatus in a metal box (except the reading instrument), and any exposed part of the circuit of the receiver enclosed in metallic tubes which are in electrical communication with the box (of course the part of the apparatus which has to receive the radiation from the distant station must not be enclosed, but possibly screened from the local transmitting instrument by means of metallic sheets).

. . . .

CLAIMS

1. The method of transmitting signals by means of electrical impulses to a receiver having a sensitive tube or other sensitive form of imperfect contact capable of being restored with certainty and regularity to its normal condition substantially as described.

3. A receiving instrument consisting of a sensitive imperfect contact or contacts, a circuit through the contact or contacts, and means for restoring the contact or contacts, with certainty and regularity, to its or their normal condition after the receipt of an impulse substantially as described.

3. A receiving instrument consisting of a sensitive imperfect contact or contacts, a circuit through the contact or contacts, and means actuated by the circuit for restoring with certainty and

regularity the contact or contacts to its or their normal condition after the receipt of an impulse.

4. In a receiving instrument such as is mentioned in claims 2 and 3, the use of resistances possessing low self-induction, or other appliances for preventing the formation of sparks at contacts or other perturbating effects.

5. The combination with the receivers such as are mentioned in claims 2 and 3 of resistances or other appliances for preventing the self-induction of the receiver from affecting the sensitive contact or contacts substantially as described.

6. The combination with receivers such as herein above referred to of choking coils substantially as described.

7. In receiving instruments consisting of an imperfect contact or contacts sensitive to electrical impulses, the use of automatically working devices for the purpose of restoring the contact or contacts with certainty and regularity to their normal condition after the receipt of an impulse substantially as herein described.

8. Constructing a sensitive non-conductor capable of being made a conductor by electrical impulses of two metal plugs or their equivalents, and confining between them some substance such as described.

9. A sensitive tube containing a mixture of two or more powders, grains, or filings, substantially as described.

10. The use of mercury in sensitive imperfect electrical contacts substantially as described.

11. A receiving instrument having a local circuit, including a sensitive imperfect electrical contact or contacts, and a relay operating an instrument for producing signals, actions, or manifestations substantially as described.

12. Sensitive contacts in which a column of powder or filings (or their equivalent) is divided into sections by means of metallic stops or plugs substantially as described.

13. Receivers substantially as described and shown in Figs. 5 and 8.

14. Transmitters substantially as described and shown at Figs. 6 and 7.

15. A receiver consisting of a sensitive tube or other imperfect contact inserted in a circuit, one end of the sensitive tube or other imperfect contact being put to earth whilst the other end is connected to an insulated conductor.

16. The combination of a transmitter having one end of its sparking appliance or poles connected to earth, and the other to an insulated conductor, with a receiver as is mentioned in claim 15.

17. A receiver consisting of a sensitive tube or other imperfect contact inserted in a circuit, and earth connections to each end of the sensitive contact or tube through condensers or their equivalent.

18. The modifications in the transmitters and receivers, in which the suspended plates are replaced by cylinders or the like placed hatwise on poles, or by balloons or kites substantially as described.

19. An induction coil having a revolving make and break substantially as and for the purposes described.

Dated this 2nd day of March, 1897.

GUGLIELMO MARCONI.

EXTRACTS FROM SPECIFICATIONS OF BR. PAT. NO. 11,575, A.D. 1897

Date of Application, May 10, 1897
Complete Specification Left, February 5, 1898
Accepted, August 10, 1898

PROVISIONAL SPECIFICATION

IMPROVEMENTS IN SYNTONIZED TELEGRAPHY WITHOUT LINE WIRES

I, OLIVER JOSEPH LODGE, D.Sc., F.R.S., of 2 Grove Park, Liverpool, in the County of Lancaster, Professor of Physics, do hereby declare the nature of this invention to be as follows:—

The object of my invention is to enable an operator to transmit messages across space to any one or more of a number of different individuals in various localities, each of whom is provided with a suitably arranged receiver.

The method consists in utilizing certain processes and apparatus for the purpose of producing and detecting rapid electric oscillations, and in so arranging them that the excitation of a particular frequency of oscillation at the sending station may cause a Morse or any other telegraphic instrument to respond at a distant station, by reason of being associated, through a relay or otherwise, with a subsidiary circuit actuated by electric oscillations of that same particular frequency, or by some multiple or sub-multiple of that frequency. Another distant station will similarly be made to receive messages by exciting at the sending station alternations of a different frequency, and so on; and thus individual messages can be transmitted to individual stations without disturbing the receiving appliances at other stations which are tuned or timed or syntonized to a different frequency. Each station will usually be provided with both sending and receiving apparatus, and messages can travel simultaneously in opposite or in cross directions without the least confusion or interference.

The sending apparatus consists of a suitable condenser or Leyden jar or other electric capacity (large or small) charged by an electrical machine or induction coil, or battery, or any other well-known means, to some considerable potential, and then discharged suddenly with a spark of any required length or shortness, occurring between suitably arranged and prepared surfaces immersed in a gaseous or a liquid

medium or *in vacuo* or in ordinary air, through a wire or other local circuit, or through the gas or water pipes of a town, or through any other local conductors which may be convenient, having coils of wire inserted or removed or shifted relatively to each other at will for the purpose of attaining any desired frequency of electric oscillation. The frequency can be adjusted either by varying the capacity of the condenser or jar or other conductor employed as the charged body, on the one hand, or by varying the number and position of coils or other portions of the discharge circuit, on the other. By means of suitable keys I propose to change easily from one rate of oscillation to another, and thus signal first to one station and then to another, using the appropriate key for each station, and manipulating it, or some other key or sending instrument in conjunction with it, so as to evoke dots and dashes or any other of the known forms of telegraphic signal at the desired station or set of stations.

The electric oscillations set up by a discharging jar have long been known to science, and the fact that such oscillations excite at a certain distance electric waves which travel through space and material bodies with the velocity of light was demonstrated by Hertz in 1888. I propose to employ a special combination of capacities with conductors or coils so arranged as to give electric oscillations of any desired frequency, so arranged also as to enable the frequency to be varied with ease and certainty, and so arranged that their effects may be transmitted to a distance either through the air or through the ground or through conductors present for other purposes or through any intervening medium whatever.

As a means of receiving or detecting those electric waves or oscillations, no matter whether the receiving station be within or beyond the distance at which true simply-progressive waves arise, I propose to use an instrument based on the " coherer " principle discovered by myself for metal in 1889 (*Journal of the Institute of Electrical Engineers*, Part 87, Vol. XIX, pp. 352-354, re-printed in " Lightning Conductors and Guards," pp. 382-384), and by Lord Rayleigh for liquids many years previously, and applied by Branly to the detection of electric waves in 1890 (see my book on " The Work of Hertz and Some of His Successors," pp. 21-24).

The " coherer," for the purpose of this invention, depends on the property which metals and liquids and other substances possess of uniting or cohering more readily under slight electric influence than when brought into mere gentle contact without such influence. Thus, at the delicately adjusted junction of two metallic or other substances, a feeble electric current, such as is sufficient to work a telegraphic relay, finds it easier to pass after the metals have been subjected to the influence of electric oscillations, e.g., of any distant electric spark or discharge, than before such influence. The original greater resistance of the light contact can be restored by a slight mechanical vibration or shock, which can be maintained automatically by any convenient means, such as the friction or percussion of clock-work, or electrical make and break, or any other shaking or

trembling mechanism, as demonstrated by me before the British Association at Oxford in 1894 in a communication entitled " an electric eye and a hypothesis concerning vision " (see the work of Hertz., etc., p. 27); or, as I prefer in carrying out this invention, by means of a continuous sound, or sound board, or by means of a coherer contact on a rotating disc or drum or other moving surface; or in general any plan whereby metallic or other contacts are established or improved by electrical means and broken or impaired by mechanical means; and whether these contacts be in air or any other medium, including vacuum.

I have also shown a pair of syntonized electric circuits, whereby electrical oscillations set up in the one are able to cause another to respond only when it is exactly " tuned " to the same frequency of vibration; a very slight change in either the capacity or the self-induction of either circuit being sufficient to throw the correspondence out. This exactitude or approximate exactitude of response depends on the fact that the total number of oscillations in a suitably arranged circuit is very great, so that a very feeble impulse is gradually strengthened until it causes a perceptible effect, on the well-known principle of sympathetic resonance. See " Modern Views of Electricity," pp. 338-340, or " Nature," Vol. XL., p. 368, 1890; also my book on the work of Hertz, etc., pp. 5 and 7.

In carrying out this invention, I propose to associate with a coherer as above described such a definitely adjusted electric circuit, to the end that the electric oscillations purposely excited at a distant station in another syntonized circuit may excite in the first one a response sufficient to disturb and temporarily alter the resistance of the coherer associated with it, so as to enable the current of a local cell or battery to pass more easily, and thereby to give any required telegraphic signal, whether by means of a relay and auxiliary battery or otherwise. There will thus be a pair of syntonized circuits, one associated with a condenser and used as transmitter, the other associated with a coherer and used as receiver.

The ordinary Hertz vibrator, and still more the radiating spheres which I have myself heretofore employed with a receiving coherer, are powerful radiators, but the vibrations are for this very reason so rapidly damped that no precision of tuning is possible; and therefore such apparatus if employed in a system of telegraphy depending on Hertzian waves is liable to disturb all receivers within range, instead of an intended selection of them. But if, as in the arrangement I employ in carrying out this invention, the radiator be partially enclosed in a metallic box or cylinder of any shape, or if an arrangement of more electrostatic capacity be employed, then although the radiation becomes less powerful, the total number of swings is so much increased that it may be made as ultimately effective at a distance as the single powerful swing; and it has the advantage of permitting precise tuning or syntonizing, so that any desired one of a number of receivers may be affected and not any of the others. Part of this invention consists therefore in an arrange-

ment whereby this desideratum becomes practically possible, as already explained, on the principles here laid down.

Dated this 8th day of May, 1897.

WM. P. THOMPSON & CO.,
6 Lord Street, Liverpool,
Patent Agents for the Applicant.

COMPLETE SPECIFICATION (ABRIDGED)

. . . .

. . . In the accompanying drawings which are diagrammatic representations,

Fig. 1 shows the simplest arrangement of emitter and receiver heretofore in use. . . . .

In carrying out my invention and referring now to the subsequent figures of the drawings, I use a definite radiator, consisting of a conductor, or pair of conductors h h^1 of large capacity arranged either as a Leyden jar or preferably spread out separately in space (one of them being the earth when desired). I join to h and h^1 respectively (which I denominate "capacity areas") a pair of polished knobs h^2 h^3 (protected by glass from ultra violet light) which form the adjustable spark gap called the "discharge gap." Between either capacity area and its knob I place a syntonizing self-inductance coil; that is a coil of wire or metallic ribbon h^4, preferably insulated with any solid or fluid insulator, as in Fig. 2, or in air, of shape suitable to attain greatest inductance with a given amount of resistance; the object of this coil being to prolong the electric oscillations occurring in the radiator, so as to constitute it a radiator of definite frequency or pitch, and obtain a succession of true waves emitted, and thereby to render syntony in a receiver possible, because exactitude of response depends on the fact that the total number of oscillations in a suitably arranged circuit is very great, so that a very feeble impulse is gradually strengthened till it causes a perceptible effect, on the well-known principle of sympathetic resonance.

I supply the electricity to the radiator from a Ruhmkorff or a Tesla coil or a Wimshurst or other known or suitable high tension machine a in one of three ways according to circumstances. . .

On the third plan as indicated in Fig. 4, I interpose in each of the wires h^8 leading from the Ruhmkorff coil a to the supply knobs a Leyden jar or other suitable condenser j able to stand a high potential, so that the knobs are supplied from the outer that is the uninsulated coat of each jar, while between the inner coats or coil terminals I arrange a third spark gap called the starting gap, also consisting of suitable knobs h^{10} h^{11}. The outer coats of the jars must not be insulated from each other, and I usually join them by a self-inductance coil of fairly thin wire k so as to permit thorough charging. When the discharge occurs, this wire acts as an alternative

path or by-pass, but does not prevent the sparks at the supply gaps.

By both of the means described with reference to Figs. 3 and 4, I charge the two capacity areas h h^1, which together with the inductance coil between them constitute the radiator by aerial disruption or impulsive rush. The advantage of this is that charges so communicated are left to oscillate free from any disturbance due to maintained connection with the source of electricity, and therefore oscillate longer and more simply than when supplied by wires in the usual way; moreover the capacity areas of a radiator are thus more conveniently employed as the capacity areas of a receiver without need of disconnection.

The arrangement described with reference to Fig. 4 illustrates most completely the method of charging the capacity areas h h^1 with an impulsive rush.

The action is as follows:—

The Ruhmkorff machine a charges the jars j, whose outer coats are connected, and discharges them at the starting gap h^{10}. This spark precipitates a discharge at the supply gaps h^7 h^8 and suddenly supplies the capacity areas h h^1 with electric charges, which then surge through the connecting coil h^4 (divided into two parts in this figure) and spark into each other at the discharge gap between the knobs h^2 h^3. This last discharge is the chief agent in starting the oscillations which are the cause of the emitted waves. But it is permissible in the arrangements of Figs. 3 and 4 to close this last gap when desired and so leave the oscillations to be started by the sparks at the supply gaps only, whose knobs must in that case be polished and protected from ultra-violet light so as to supply the electric charge in as sudden a manner as possible.

As charged surfaces or capacity areas, spheres or square plates or any other metal surfaces may be employed, but I prefer, for the purpose of combining low resistance with great electrostatic capacity, cones or triangles or other such diverging surfaces, with the vertices adjoining and their larger areas spreading out into space. Or a single insulated surface may be used in conjunction with the earth, the earth or conductors embedded in the earth constituting the other oppositely charged surface. Radiation from an oscillator consisting of a pair of capacity areas is greater in the equatorial than in the axial direction, and accordingly, when sending in all directions is desired, it is well to arrange the axis of the emitter vertical. Moreover, radiation polarized in a horizontal plane, that is with its electric oscillations vertical, is less likely to be absorbed during its passage over partially conducting earth or water. A pair of insulated capacity areas arranged for long-distance signalling is shown on the left-hand side of Fig. 5.

Fig. 6 shows a single insulated capacity area h with the earth acting as the other surface and leading up to the spark knobs h^2 h^3 by a triangular sheet or cone h^1 so as to afford good conductance even to rapidly alternating currents. The wire h^8 in this case leads

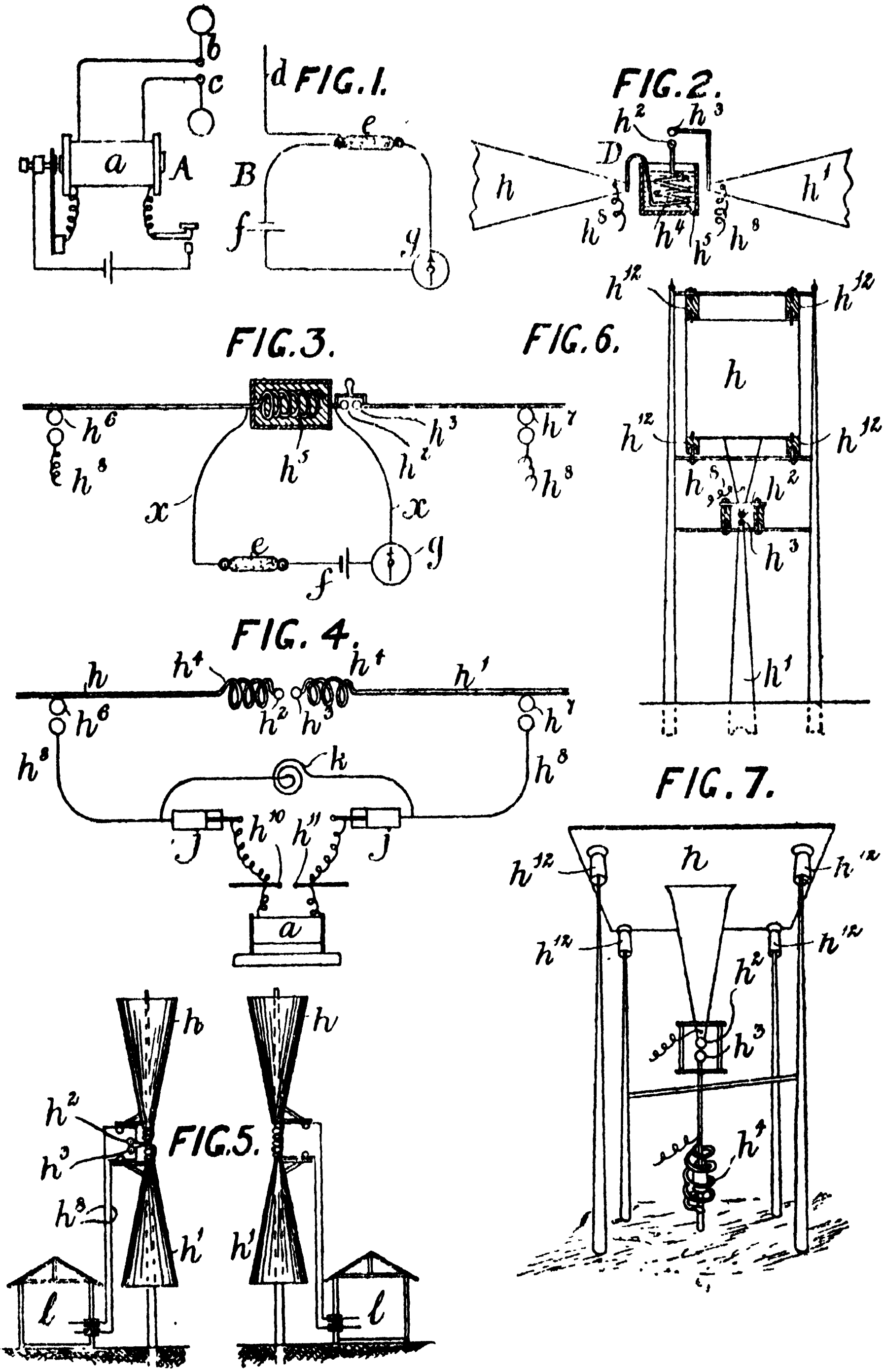


Fig. VI,

I

to one terminal of the Ruhmkorff coil *a*, the other terminal of which is taken to earth as shown. The capacity area *h* is insulated as indicated at h^{12}. . . . .

A coherer consists of any arrangement which drops in resistance on receipt of an electric impulse, and rises to its old resistance on being subjected to a mechanical impulse such as a tremor or a tap.

A coherer circuit is any known arrangement for observing or recording effects due to fluctuations in the electrical resistance of a coherer.

As coherer I may use Branly's arrangement of a pair of conductors embedded in metallic grains or powder or filings, but I prefer selected iron filings of uniform size sealed up in a good vacuum and with the communicating surfaces or electrodes reduced to points or thin platinum wires fused into the glass and with their ends close together. . . . .

Whenever an electric wave or impulse from a distant radiator arrives and stimulates electric vibrations in the syntonized resonator or absorber arranged for the purpose, the delicately adjusted junction of the two metals or of the metallic or other particles which are connected up to the resonator so as to feel these vibrations suddenly and greatly changes its electrical resistance, and this diminished resistance enables a local battery to actuate a relay or a telephone or other telegraphic instrument in circuit therewith.

To break contact again, or to restore the original greater resistance, any form of mechanical vibration suffices. . . .

The diminution of resistance takes place instantaneously, and contact is broken again in a very small fraction of a second later. The instant it is broken the junction is ready to receive a fresh signal. The rapidity of signalling depends on the quickness of response of the signalling instrument, and it depends also on the rapidity with which the mechanical arrangement can break or interrupt the cohesion directly after the electrical stimulus has established it. When a telephone is used I find that the coherer restores itself sufficiently without specially arranged tremor and that a telephone is the quickest responder that can be used.

As coherer circuit, I usually arrange the coherer in simple series with a battery (voltaic or thermal) and a galvanometer or other indicator or recorder of fluctuations of current, and I then connect the terminals of this series of instruments to the capacity areas of the receiver close to its self-inductance coil, so that this same coil of wire completes and forms an essential part of the coherer circuit. The coherer is thus affected by every electrical disturbance occurring in the connecting coil or in its capacity areas, and by aid of the battery at once enables the telegraphic or telephonic instrument to appreciate and indicate the signals. This plan is shown in Fig. 13.[1] It is an improvement on any mode of connection that had previously been possible without the connecting coil.

In some cases I may, as shown in Fig. 14,[1] surround the

[1] Page 133.

syntonizing coil of the resonator with another or secondary coil *u* (constituting a species of transformer) and make this latter coil part of the coherer circuit, so that it shall be secondarily affected by the alternating currents excited in the conductor of the resonator, and thus the coherer be stimulated by the current in this secondary coil rather than primarily by the currents in the syntonizing coil itself; the idea being thus to leave the resonator freer to vibrate electrically without disturbance from attached wires.

In all cases it is permissible and sometimes desirable to shunt the coils of the telegraphic instrument by means of a fine wire or other non-inductive resistance, as shown at *w* in Fig. 13, in order to connect the coherer more effectively and closely to the capacity areas or receiving arrangement whereby it is to be stimulated.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. In a system of Hertzian wave telegraphy, the combination with a pair of capacity areas (of which one may be the earth) of a self-inductance coil inserted between them electrically, for the purpose of prolonging any electrical oscillations excited in the system, and constituting such a system a radiator of definite frequency or pitch.

2. In a system of Hertzian wave telegraphy, the combination with a pair of capacity areas (of which one may be the earth), of a self-inductance coil inserted between them electrically for the purpose of prolonging any electrical oscillations excited in the system and thereby enabling a distant radiator to act cumulatively if of corresponding period; thus constituting the system a resonator or absorber of definite frequency or pitch.

3. In combination, a pair of capacity areas connected by a coil of wire serving as the radiator in a system of Hertzian wave telegraphy, means for syntonizing such radiator and means for charging it by aerial disruption or impulsive rush.

4. In a system of Hertzian wave telegraphy, the combination of a pair of capacity areas such as h h^1, means for syntonizing such capacity areas, a receiving circuit completed through one or both of such capacity areas or their adjuncts, and means for bridging over the discharge gap between such capacity areas when they are to be used as a receiver whereby such capacity areas are rendered adaptable for use at will either as a radiator or resonator.

5. In a system of syntonic Hertzian wave telegraphy the combination with the self-inductance coil of the receiver of a secondary coil surrounding the same, which secondary coil forms part of the coherer circuit substantially as and for the purpose set forth.

6. The combination, in the receiving circuit of a system of Hertzian wave · telegraphy, of an adjustable or replaceable self-inductance coil, connecting the capacity areas, a coherer, a battery, a telegraphic receiving instrument or a telephone with or without a shunt across the coils thereof substantially as and for the purpose set forth.

7. The construction arrangement and combination of parts constituting my improved system of syntonic Hertzian wave telegraphy substantially as set forth and as illustrated in the accompanying drawings.

Dated this 1st day of February, 1898.

WM. P. THOMPSON & CO.,
Patent Agents,
Of Liverpool, Manchester, Birmingham and London.

AUTHOR'S NOTE.—On the 28th day of April, 1911, Mr. Justice Parker amended this patent by deleting four other claims, and extended it for seven years, subject to compulsory license.

SPECIFICATION OF BR. PAT. NO. 22,020, A.D. 1899

Date of Application, November 3, 1899
Complete Specification Left, June 30, 1900
Accepted, September 22, 1900

[Communicated from abroad by PROFESSOR FERDINAND BRAUN, of Strassburg, in the Empire of Germany, Doctor of Philosophy.]

COMPLETE SPECIFICATION

IMPROVEMENTS IN OR RELATING TO TELEGRAPHY WITHOUT THE USE OF CONTINUOUS WIRES

This invention relates to telegraphy without the use of connecting wires between the receiver and transmitter.

Fig. 1 shows a diagram of the connection of the apparatus, Fig. 2 is a modification thereof.

Hitherto it has been usual in such telegraphy to arrange the spark gap in the current circuit of the vertical transmitting wire as has been already set forth by Popoff and induction coils have been joined in the said circuit. I have found, however, that much better results are obtainable, if the currents which pass through the spark gap are not allowed to pass immediately into the transmitting wire, but are previously transformed. Therefore I provide the spark gap in the current of the primary coil of a transformer, the secondary coil of which is connected to the transmitting wire at one end, its other end being connected to earth or insulated. This method proves to be specially advantageous if use is made not of the quick waves hitherto usual, but of slower waves, such as are obtained by the discharge of Leyden jars. The advantage of using transformed current for electrical telegraphy is increased if slower vibrations are produced. To give a theoretical explanation of my invention presents difficulty. Possibly the sparking gap in the oscillating circuit exercises a damping effect so that the vibrations soon disappear. There may, however, be other causes for this effect.

When slower vibrations are made use of, each vibration of the

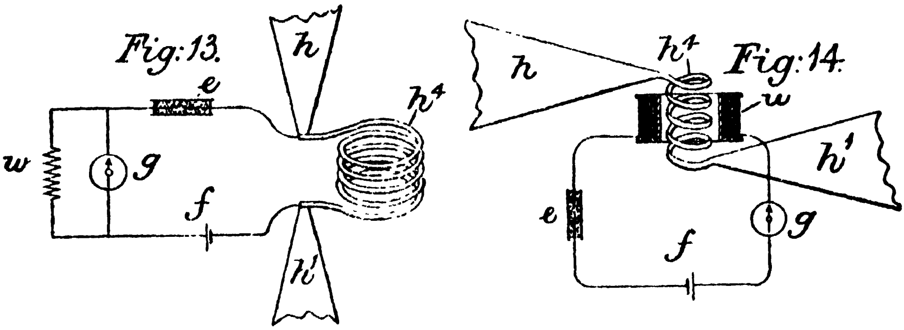


Fig. VI*a*. Lodge's Coupled-circuit Receiver (see page 130).

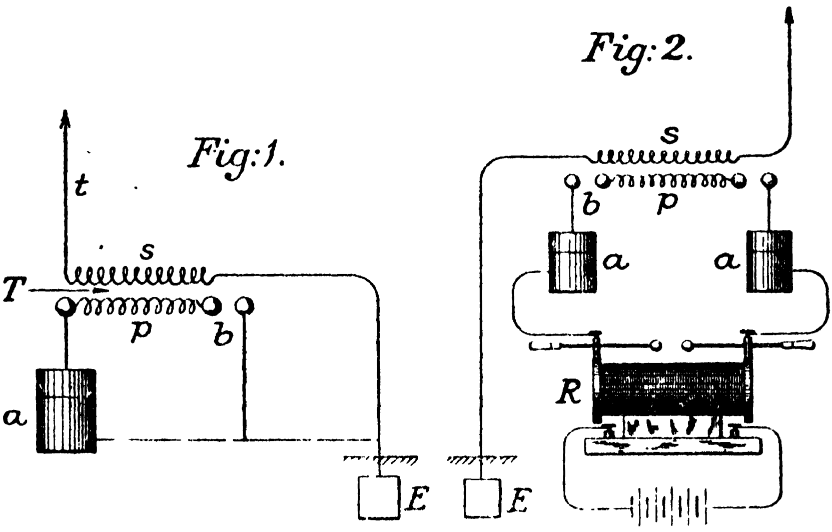


Fig. VII. Braun's Coupled-circuit Transmitter.

primary current circuit will cause a vibration of the secondary circuit; in addition to this, however, also the proper vibrations of the secondary current circuit will be superposed. It appears not impossible that the reason of the improved transmission may lie in this peculiar effect. Whether this explanation be the correct one or not, the fact remains that the electric signals of telegraphy without a continuous wire are clearer and plainer than it is ever possible to obtain with non-transformed vibrations. There is, moreover, another advantage in that the transmitting wire is not in direct connection with the high tension, and consequently that a fall of the wire would not have the same injurious effects which would be caused in the case of a direct connection. Indeed the said wire can be touched by persons without injury.

In Fig. 1 *a* is a Leyden jar which is discharged through the air at *b* and the primary coil *p* of transformer T. One end of the secondary coil *s* is connected with the earth E, the other with the transmitting wire *t*.

In Fig. 2 R means a Ruhmkorff apparatus connected with the Leyden jars *a*, the spark gaps *c*, and the primary and secondary wire *p* and *s*. The connection of the secondary may be effected in the same manner as before.

The receiving devices (not shown in the figures) are of the usual type, viz., a coherer, a local battery, a signaller and so on.

Having now particularly described and ascertained the nature of this invention, and in what manner the same is to be performed, I declare that what I claim is:—

In electric wireless telegraphy the use of transformers the primary of which is joined in the circuit of the air gap and the secondary of which is connected with the sending wire.

Dated the 30th day of June, 1900.

W. P. THOMPSON & CO.,
Of London, Liverpool, Manchester and Birmingham.

EXTRACTS FROM THE SPECIFICATION OF BR. PAT. NO. 7777, A.D. 1900

Date of Application, April 26, 1900
Complete Specification Left, February 25, 1901
Accepted, April 13, 1901

COMPLETE SPECIFICATION

IMPROVEMENTS IN APPARATUS FOR WIRELESS TELEGRAPHY

We, GUGLIELMO MARCONI, Electrician, and MARCONI'S WIRELESS TELEGRAPH COMPANY, LIMITED, late of 28 Mark Lane, and now both of 18 Finch Lane, in the City of London, do hereby declare the nature

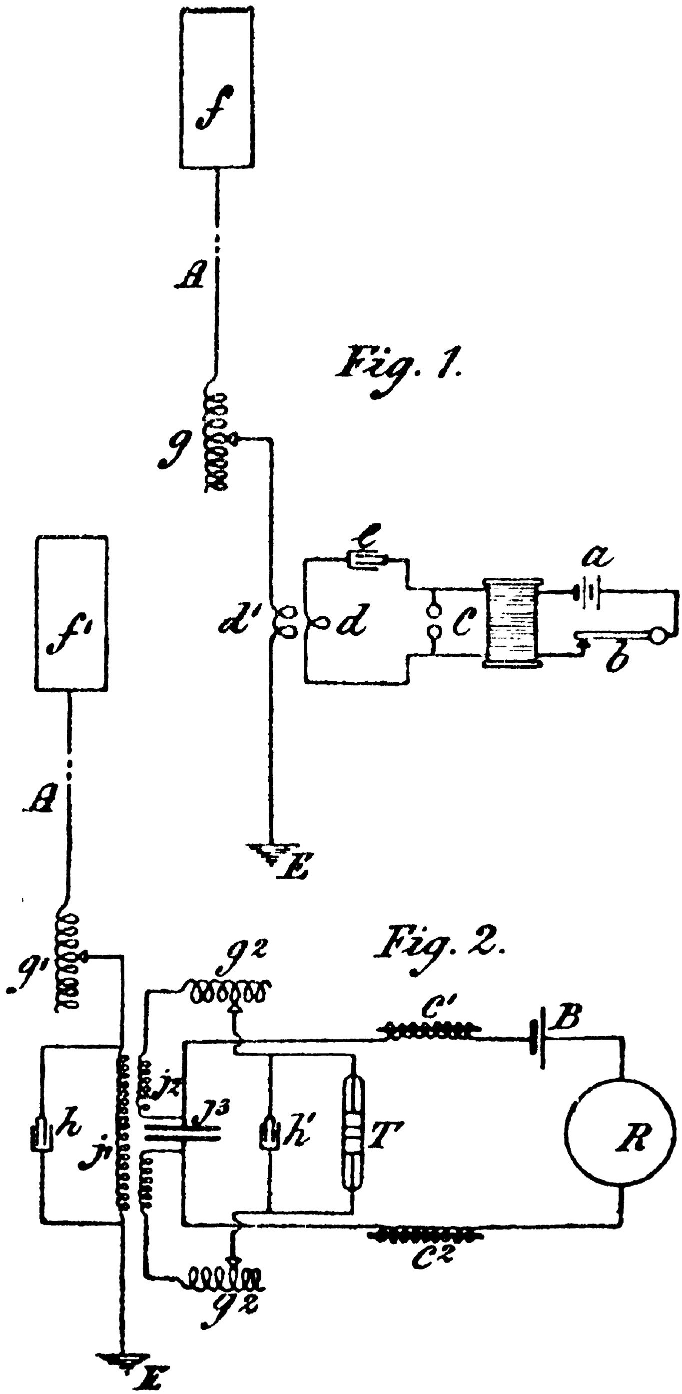


Fig. VIII.

of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The object of this invention is not only to increase the efficiency of the apparatus hitherto employed, but also to so control the action as to cause intelligible communications to be established with one or more stations only out of a group of several receiving stations.

In the Specification of a former Patent No. 12,039 of 1896, a transmitter is described which consists of an induction coil, one terminal of the secondary circuit being connected to a metal sphere connected to earth and the other to a similar sphere connected to an insulated conductor which generally takes the form of a more or less vertical wire which may or may not terminate in or have attached to it a metal body of extended surface, giving it increased electrical capacity.

According to the present invention the vertical wire is connected to earth through the secondary winding of a transformer of a kind suitable for the transformation of very rapidly alternating electric currents and the primary of this transformer is connected to the spheres or terminals of the sparking appliance.

A condenser of suitable capacity is introduced in series with the primary or each end of the primary may be connected to one of the plates of two condensers of suitable capacity, the other plates of which are connected to the sparking appliance.

This device enables much more energy to be imparted to the radiator than heretofore, the approximately closed circuit of the primary being a good conserver and the open circuit of the secondary a good radiator of wave energy.

The arrangement works as follows:—

On pressing the key and actuating the induction coil (in order to produce a signal) the condenser in circuit with the transformer is charged and subsequently discharges through the spark gap. If the capacity, the inductance, and the resistance of the circuit are of suitable values, the discharge is oscillatory, with the result that alternating currents of high frequency pass through the primary of the transformer, and induce similar oscillations in its secondary, these oscillations being communicated to the elevated conductor.

The circuit of the elevated conductor should be suitably attuned for this purpose.

The effect of these oscillations in the elevated conductor is to inductively affect similar distant conductors if the self-induction and capacity of the said conductors is of a suitable value or values.

At the receiving end a receiver is employed capable of being actuated by electrical oscillations of high frequency such as are described in the Specifications Nos. 12,326 of 1898, 6982 of 1899, and 25,186 of 1899.

The four circuits, namely those including the primary and the secondary of the transformer in the transmitter and the primary and secondary of the transformer in the receiver, should be so adjusted

as to make the electric time period the same in each, i.e., the product of the self-induction multiplied by the capacity is the same in each case. But in lieu of the time periods being the same in each they may be harmonics of each other.

In employing this invention to localize the transmission of intelligence from a station to one only out of several receiving stations the time period of the circuits at each of these stations is so arranged as to be the same but different from those of the other receiving stations. If the time period of the circuits of the transmitting station are varied until they are in resonance with those of one of the receiving stations that one alone out of all the number of receiving stations will respond, provided that the distance between the transmitter and receiver is not too small.

The adjustment of the self-induction and capacity of the circuits can be made in any convenient manner. As a practical guide to putting the invention in practice we subjoin the arrangements which we find work best.

Figs. 1 and 2 are diagrams of the transmitter and of the receiver respectively. . . . .

TRANSMITTING STATION.

Tune	Aerial Conductor	Transformer $d\ d^1$	Inductance Number of turns of g included	Capacity in microfarads e	Length of spark in millimetres
No. 7	Four vertical wires each 48·6 metres long connected together at top and bottom but kept apart throughout their length by being suspended from the arms of a wooden cross each of which is 4 metres long.	No. 4	None	·016	6
No. 8	One vertical wire 48 metres long	No. 5	None	·007	6

Tunes Nos. 7 and 8 give very good signals over a distance of 190 miles.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A transmitter for electric wave telegraphy consisting of a spark producer having its terminals connected through a condenser with one circuit of a transformer, the other circuit being connected to a conductor and to earth or a capacity, the time period of electrical

oscillations in the two circuits being the same or harmonics of each other.

2. A system of electric wave telegraphy in which both the transmitter and the receiver contain a transformer, the time period of electrical oscillations in the four circuits of the two transformers being the same or harmonics of each other.

3. A system of electrical wave telegraphy in which both the transmitter and the receiver contain a transformer one circuit of which is a persistent oscillator and the other a good radiator or absorber of electrical oscillations, all four circuits having the same time period or being harmonics of each other substantially as described.

4. Apparatus for wireless telegraphy substantially as described and illustrated in the drawings.

Dated this 25th day of February, 1901.

G. MARCONI,
MARCONI'S WIRELESS TELEGRAPH CO., LTD.,
By Carpmael & Co.,
Agents.

EXTRACTS FROM BR. PAT. NO. 20,981, A.D. 1896

Date of Application, September 22, 1896
Accepted, November 21, 1896

COMPLETE SPECIFICATION

[Communicated from abroad by Nikola Tesla, of 46 East Houston Street, New York, United States of America, Electrician.]

Improvements relating to the Production, Regulation, and Utilization of Electric Currents of High Frequency, and to Apparatus therefor.

I, Henry Harris Lake, of the Firm of Haseltine, Lake & Co., Patent Agents, 45 Southampton Buildings, in the County of Middlesex, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention, subject of the present application, is embodied in certain improvements in methods of and apparatus for producing, regulating and utilizing electric currents of high frequency heretofore invented by Nikola Tesla, and described in British Letters Patent No. 8575, dated May 19, 1891. The method and apparatus referred to in said patent were devised for the purpose of converting, supplying

and utilizing electrical energy in a form suited for the production of certain novel electrical phenomena which require currents of high potential and a higher frequency than can readily or even possibly be developed by generators of the ordinary types or by such mechanical appliances as were theretofore known. The invention referred to was based upon the principle of charging a condenser or a circuit possessing capacity and discharging the same, generally through the primary of a transformer, the secondary of which constituted the source of working current, and under such conditions as to yield a vibratory or rapidly intermittent discharge current.

The present invention, while aiming to simplify and render more efficient the apparatus heretofore used, has for its object, primarily, to provide a means for converting such currents as are generally and most readily obtainable from the mains of ordinary systems of municipal distribution, into currents of the special character referred to, and to regulate or control, and utilize such currents in a simple, economical and efficient manner. The improvements are illustrated herein in forms of apparatus adapted for use with existing circuits or systems, and which while constructed and operating on the same general principles are modified only as may be required by a direct or an alternating source of supply. . . . .

When the potential of the source of current periodically rises and falls, whether with reversals or not is immaterial, it is essential to economical operation that the intervals of interruption of the charging circuit should bear a definite time relation to the period of the current, in order that the effective potential of the impulses charging the condenser may be as high as possible. In case, therefore, an alternating or equivalent electromotive force be employed as the source of supply, a circuit controller is used which will interrupt the charging circuit at instants predetermined with reference to the variations of potential therein.

A convenient, and probably the most practicable means for accomplishing this is a synchronous motor connected with the source of supply and operating a circuit controller which first interrupts the charging current at or about the instant of highest intensity of each wave and then permits the condenser to discharge the energy stored in it, through its appropriate circuit. Such apparatus, which may be regarded as typical of the means for accomplishing this purpose, is illustrated in Figs. 4, 5 and 6.

In Fig. 4, A^{11} A^{11} are the conductors taken from the mains of any alternating current generator A, and for raising the potential of such current a transformer is employed represented by the primary B and secondary B^1.

The circuit of the secondary includes the energizing coils of a synchronous motor G, and a circuit controller C fixed to the shaft of the motor.

An insulating arm O, stationary with respect to the motor shaft and adjustable with reference to the poles of the fixed magnets, carries two brushes F F^1 which bear upon the periphery of the disk C.

With the parts thus arranged, the secondary circuit is completed through the coils of the motor whenever the two brushes rest upon the uninsulated segments of the disk, and interrupted through the motor at other times.

Such a motor, if properly constructed, in well understood ways, maintains very exact synchronism with the alternations of the source, and the arm O may, therefore, be adjusted to interrupt the current at any determined point of its waves. By the proper relations of insulated and conducting segments, and the motor poles, the current may be interrupted twice in each complete wave at or about the points of highest intensity.

In order that the energy stored in the motor circuit may be utilized at each break to charge the condenser H, the terminals of the latter are connected to the two brushes F F^1 or to points of the circuit adjacent thereto, so that when the circuit through the motor is interrupted the terminals of the motor circuit will be connected with the condenser. The discharge of the condenser takes place through the primary K, the circuit of which is completed simultaneously with the motor circuit and interrupted while the motor circuit is broken and the condenser being charged. The secondary impulses of high potential and great frequency are available for the operation of vacuum tubes P, single terminal lamps R, and other novel and useful purposes.

It is obvious that the supply current need not be alternating, provided it be converted or transformed into an alternating current, before reaching the controller. . . . .

In some cases the energy delivered by the system may be readily and economically regulated. It is well known that every electric circuit, provided its ohmic resistance does not exceed certain definite limits, has a period of vibration of its own analogous to the period of vibration of a weighted spring. In order to alternately charge a given circuit of this character by periodic impulses impressed upon it and to discharge it most effectively, the frequency of the impressed impulses should bear a definite relation to the frequency of vibration possessed by the circuit itself. Moreover, for like reasons, the period of vibration of the discharge circuit should bear a similar relation to the impressed impulses or the period of the charging circuit. When the conditions are such that the general law of harmonic vibrations is followed, the circuits are said to be in resonance or in electro-magnetic synchronism, and this condition of the system is found to be highly advantageous.

In carrying out the invention, therefore, the electrical constants should be so adjusted that in normal operation the condition of resonance is approximately attained. To accomplish this, the number of impulses of current directed into the charging circuit per unit time is made equal to the period of the charging circuit itself, or, generally, to a harmonic thereof, and the same relations are maintained between the charging and discharge circuit. Any departure from this condition will result in a decreased output, and this fact is

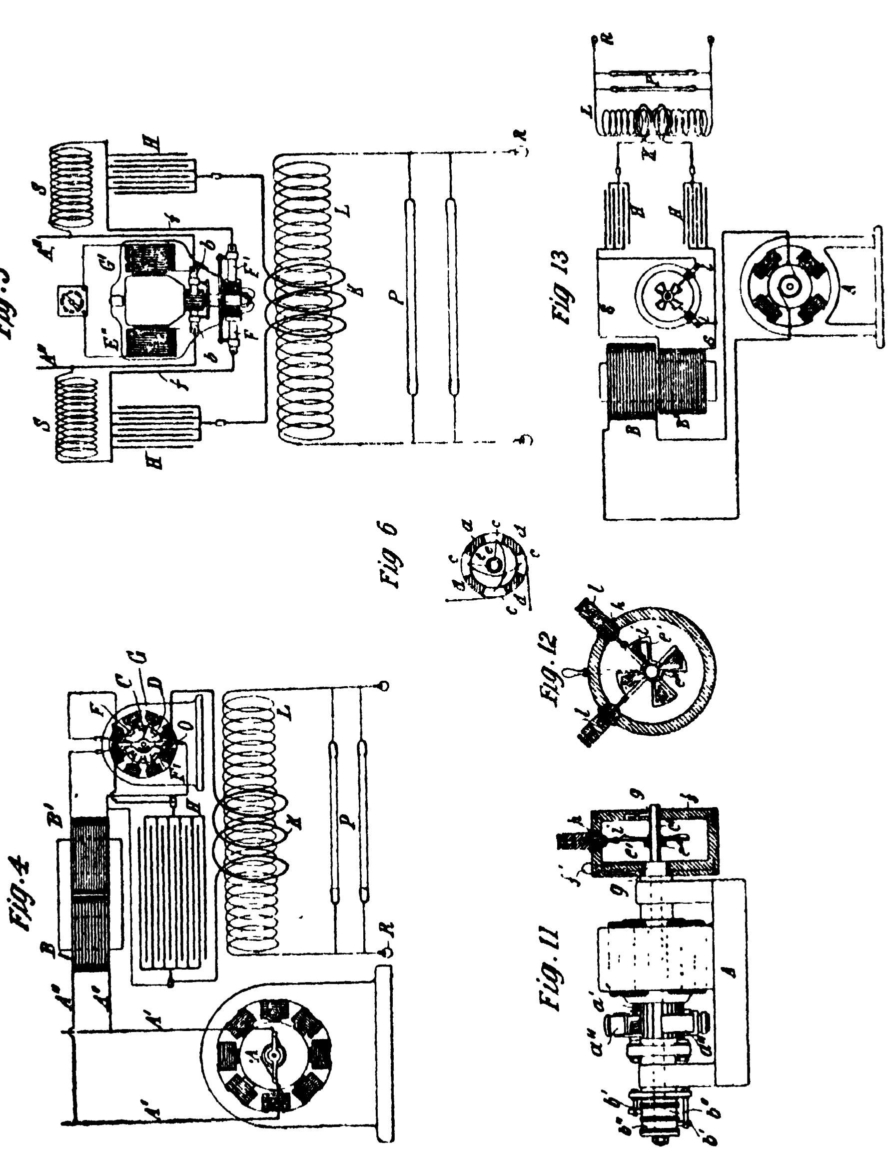


Fig. IX.

taken advantage of in regulating such output by varying the frequencies of the impulses or vibrations in the several circuits.

Inasmuch as the period of any given circuit depends upon the relations of its resistance, self-induction and capacity, a variation of any one or more of these may result in a variation of its period. . . .

In order to secure the greatest efficiency in a system of this kind, it is essential, as before stated, that the circuits, which mainly as a matter of convenience are designated as the charging and the discharge circuits, should be approximately in resonance or electromagnetic synchronism. Moreover, in order to obtain the greatest output from a given apparatus of this kind it is desirable to maintain as high a frequency as possible. . . . .

The circuit controller or the device which ensures the proper charging and discharging of the condenser may be of any construction that will perform the functions required of it. In illustration of the principle of construction and mode of operation, reference has been made only to forms of mechanism that make and break metallic contacts, but there need be no actual metallic contact, if provision be made for the passage of a spark between separated conductors. Such a device is illustrated in Figs. 11 to 15.

A designates, in Fig. 11, a generator having a commutator a^1 and brushes a^{11} bearing thereon, and also collecting rings b^{11}, b^{11}, from which an alternating current is taken by brushes b^1 in the well-understood manner. . . . .

Having now particularly described and ascertained the nature of the said invention and in what manner the same is to be performed, as communicated to me by my foreign correspondent, I declare that what I claim is:—

1. The apparatus herein described for converting electric currents of the kind generally obtainable from municipal systems of electric distribution, into currents of high frequency, comprising in combination a circuit of high self-induction, a circuit controller adapted to make and break such circuit, a condenser into which the said circuit discharges when interrupted, and a transformer through the primary of which the condenser discharges, as set forth. . .

6. The method herein described of converting alternating currents of relatively low frequency into currents of high frequency, which consists in charging a condenser by such currents of low frequency during determinate intervals of each wave of said current; and discharging the condenser through a circuit of such character as to produce therein a rapid succession of impulses, as set forth. . .

14. The combination with a source of alternating current, of a condenser adapted to be charged thereby, a circuit into which the condenser discharges in a series of rapid impulses, and a circuit controller for effecting the charging and discharge of said condenser composed of conductors movable into and out of proximity with each other in synchronism with the alterations of the source, as set forth.

15. A circuit controller for systems of the kind described, comprising in combination a pair of angularly adjustable terminals

and two or more rotating conductors mounted to pass in proximity to the said terminals, as set forth.

16. A circular controller for systems of the kind described, comprising in combination two sets of conductors, one capable of rotation and the other of angular adjustment whereby they may be brought into and out of proximity to each other at determinate points and one or both being subdivided so as to present a group of conducting points, as set forth.

Dated this 22nd day of September, 1896.

HASELTINE, LAKE & CO.,
Agents for the Applicant,
45 Southampton Buildings, London, W.C.

UNITED STATES PATENT OFFICE

THOMAS A. EDISON, OF MENLO PARK, NEW JERSEY

ELECTRICAL INDICATOR

SPECIFICATION FORMING PART OF LETTERS PATENT NO. 307,031, DATED OCTOBER 21, 1884 (ABRIDGED)

Application filed November 15, 1883. (*No model.*)

To all whom it may concern:

Be it known that I, THOMAS A. EDISON, of Menlo Park, in the county of Middlesex and State of New Jersey, have invented a new and useful Improvement in Electrical Indicators (Case No. 603), of which the following is a specification.

The object of my invention is to produce an efficient apparatus for indicating variations of electro-motive force in an electric circuit, preferably for use in connection with systems of electrical distribution to show the changes in pressure in the various parts of the district. The apparatus is also capable of use in automatically regulating the electro-motive force to correspond with such variations. I have discovered that if a conducting substance is interposed anywhere in the vacuous space within the globe of an incandescent electric lamp, and said conducting substance is connected outside of the lamp with one terminal, preferably the positive one, of the incandescent conductor, a portion of the current will, when the lamp is in operation, pass through the shunt-circuit thus formed, which shunt includes a portion of the vacuous space within the lamp. This current I have found to be proportional to the degree of incandescence of the conductor or candle-power of the lamp.

My invention consists in the utilization of this discovery for indicating or regulating variations in electro-motive force, or for affecting electrical apparatus in any desired manner. . . .

The wire 5 leads to the binding-post *c*, while a wire 6, connected with the positive wire 3 of the lamp, leads to the binding-post c^1.[1] . . . .

What I claim is—

4. The combination, with an incandescent electric lamp, of a circuit having one terminal in the vacuous space within the globe of said lamp, and the other in connection without the lamp with the positive side of the lamp-circuit, substantially as set forth.

This specification signed and witnessed this 2nd day of November, 1883.

THOS. A. EDISON.

Witnesses:
H. W. Seely,
Edward H. Pyatt.

EXTRACT FROM SPECIFICATION OF BR. PAT. NO. 24,850, A.D. 1904

Date of Application, November 16, 1904
Complete Specification Left, August 15, 1905
Accepted, September 21, 1905

COMPLETE SPECIFICATION

Improvements in Instruments for Detecting and Measuring Alternating Electric Currents

I, John Ambrose Fleming, of University College, Gower Street, in the County of London, Doctor of Science, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to certain new and useful devices for converting alternating electric currents and especially high frequency alternating electric currents or electric oscillations into continuous electric currents for the purpose of making them detectable by, and measurable with, ordinary direct current instruments such as a "mirror galvanometer" of the usual type or any ordinary direct current ammeter.

Such instruments as the latter are not affected by alternating electric currents either of high or low frequency which can only be measured and detected by instruments called alternating current instruments of special design. It is, however, of great practical importance to be able to detect feeble electric oscillations, such as are employed in Hertzian wave telegraphy by an ordinary movable coil or movable needle mirror galvanometer. This can be done if the alternating current can be "rectified," that is either suppressing all the constituent electric currents in one direction and preserving the

[1] Drawings on following page.

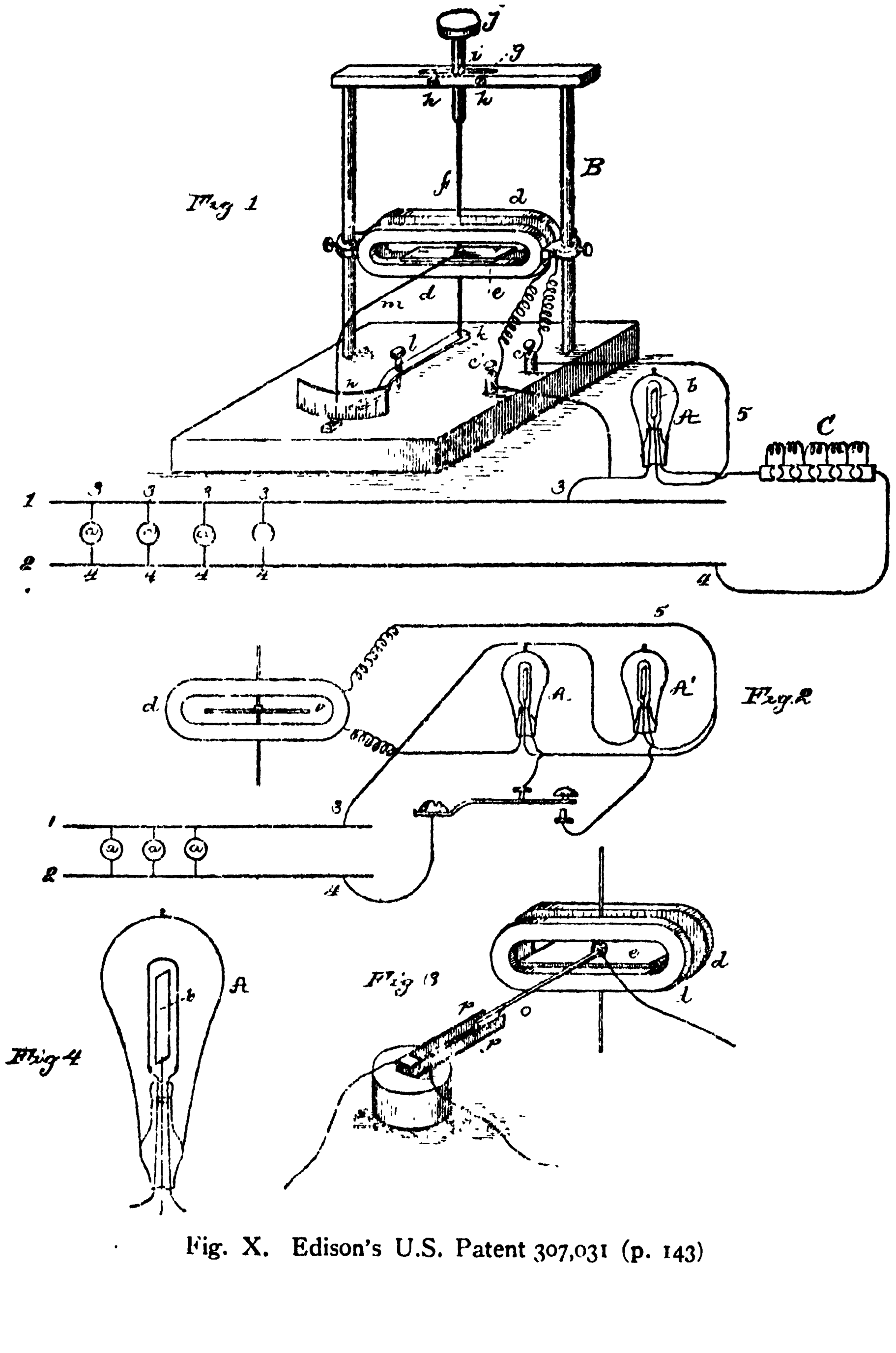


Fig. X. Edison's U.S. Patent 307,031 (p. 143)

K

others, or else by changing the direction of one of the sets of currents which compose the alternating current so that the whole movement of electricity is in one direction. Many means have been devised and are in use for rectifying low frequency alternating currents, such as are used in electric lighting. There are well-known forms of mechanical rectifier, also there is a well-known form of electro-chemical rectifier depending on the fact that when a plate of carbon and aluminium is placed in any electrolyte which yields oxygen on electrolysis, an electric current can only pass through this cell in one direction if below a certain voltage.

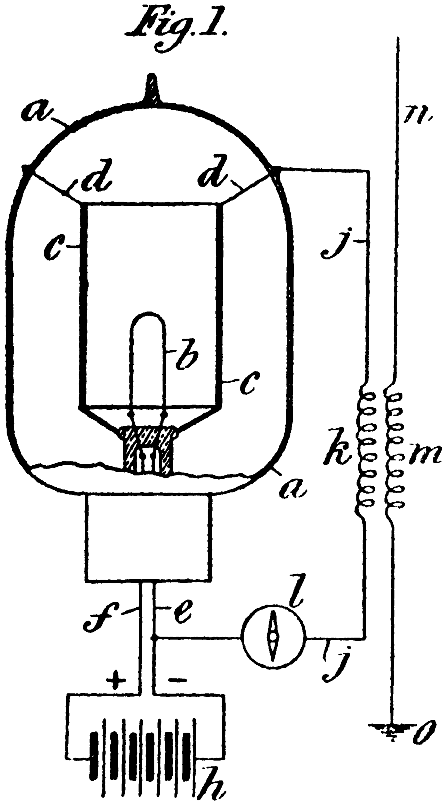


Fig. XI.

Both these forms of rectifier are, however, inapplicable for high frequency currents. I have found that the aluminium-carbon cell will not act with high frequency currents.

I have discovered that if two conductors are enclosed in a vessel in which a good vacuum is made, one being heated to a high temperature, the space between the hot and cold conductors possesses a unilateral electric conductivity, and negative electricity can pass from the hot conductor to the cold conductor but not in the reverse direction. . . . As a very high vacuum should be obtained in the bulb *a* and as a considerable quantity of air is occluded in the conductors these should be heated when the bulb is being exhausted. . . . Although Fig. 1 shows the application of the instrument to wireless telegraphy it will be understood that the aerial wire *n* may be replaced by any circuit in which there is an alternating electromotive force, whether of low frequency or of high frequency. . . . The galvanometer *l* may be replaced by any other instrument for detecting the oscillations or by a relay for actuating a detecting or recording instrument.

In those cases in which a larger alternating current has to be dealt with, the hot conductor may be a rod of soft graphitic carbon held in suitable supports.

I find it possible by means of the device described above to rectify an alternating current without the use of any auxiliary

continuous heating current. Thus, if I pass through the carbon filament an alternating current to bring it to bright incandescence, I find if I connect either terminal of the filament by a circuit outside the bulb with the terminal of the embracing cylinder or other cold conductor, then in this circuit a continuous current flows. Hence, the device may be used for rectifying either high frequency or low frequency alternating currents of electrical oscillations, provided these are of sufficient strength to render a carbon filament brilliantly incandescent.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. A vacuous vessel having in it two conductors adjacent to but not touching each other, one of them being heated, these conductors being connected by a circuit outside the vessel, such circuit being exposed to some influence tending to produce an alternating current in it and which contains a galvanometer or other instrument for detecting a continuous current substantially as described.
2. In instruments such as are covered by Claim 1, heating the conductor by means of a continuous electric current passed through it substantially as described.
3. The application of the instruments covered by Claims 1 and 2 to wireless telegraphy substantially as described.
4. Duplicating the instruments covered by Claims 1, 2 and 3, by connecting the two coils of a differential galvanometer respectively to the heated conductor in one vessel and the unheated conductor in the other, the connection between the two coils being connected to the other pair of conductors substantially as described.
5. Instruments for converting alternating electric currents into unilateral currents substantially as described.

Dated this 1st day of August, 1905.

J. A. FLEMING.

Author's Note.—This specification was amended by disclaimer in 1918 when the patent expired, and an application was unsuccessfully made for its extension.

UNITED STATES PATENT OFFICE

LEE DE FOREST, OF NEW YORK, N.Y.

DEVICE FOR AMPLIFYING FEEBLE ELECTRICAL CURRENTS

SPECIFICATION OF LETTERS PATENT NO. 841,387.
PATENTED JANUARY 15, 1907 (ABRIDGED)

Application filed October 25, 1906. *Serial No.* 340,467

To all whom it may concern:

Be it known that I, LEE DE FOREST, a citizen of the United States, and a resident of New York, in the county of New York and State of New York, have invented a new and useful Improvement in Devices for Amplifying Feeble Electrical Currents, of which the following is a specification.

My invention relates to devices for amplifying feeble electrical currents—such, for example, as telephone-currents; and its object is to produce an amplifying device of greater efficiency and simplicity than those heretofore employed.

My invention will be described with reference to the drawings accompanying and forming a part of this specification, and in which—

Figs. 1, 2, 4 and 5 represent conventionally or diagrammatically various arrangements of apparatus and circuits whereby my invention may be carried into effect.

In the figures, A represents an evacuated vessel inclosing a sensitive conducting gaseous medium maintained in a condition of molecular activity.

R is a signal-indicating device.

B B^1 are batteries or other sources of electrical energy.

D E D^1 are electrodes sealed within the receptacle A. . .

In Fig. 2 the current to be amplified may be impressed upon the medium intervening between the electrodes D and E, and thereby alter, by electrostatic attraction, the separation between the electrodes. In this case D^1 may be a strip of platinum-foil, and the slightest approach thereof toward the filament will act to slightly cool the gaseous medium, and thereby alter the current in the local circuit, or, if D^1 is rigid, the increase in electrostatic attraction between D^1 and E will cause E to recede from D, and thereby alter the current in the local circuit. . . . .

In Fig. 4 the currents to be amplified may be impressed upon the gaseous medium intervening between D^1 and E by means of the transformer M^1. A condenser C may be included in series with the secondary of said transformer and the electrodes D^1 E. In this case there may or may not be a variation between the separation of the electrodes, and the currents to be amplified may vary the motions of

the ions around the filament, thereby controlling to a greater degree the flux between said filament and the electrode D. . . .

It will be obvious that the amplifying device, which constitutes the subject-matter of the present invention, is not limited in its use to any particular kind of electrical circuit or apparatus, but that it is capable of general application wherever an amplifying device is required. By way of example of its application to a wire telegraph

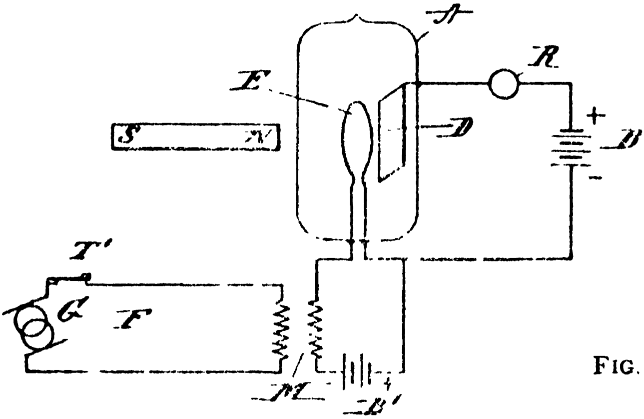


FIG. 1

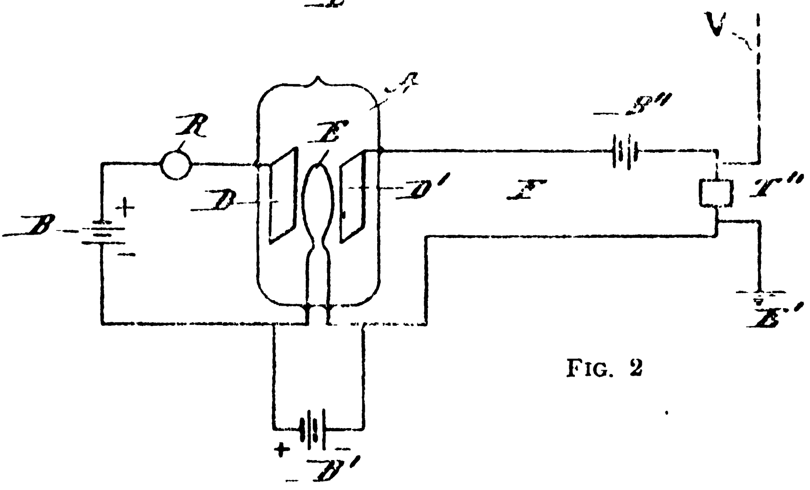


FIG. 2

Fig. XII.

or cable system I have shown the line F in Fig. 1 as including a telegraph transmitting-key T^1 and source of vibratory current G. In Fig. 2 I have shown the line F as constituting the local circuit of a wireless-telegraph receiving system including the battery B^{11} and oscillation-detector T^{11}, the latter being connected in series with an antenna V and the earth E^1. In Fig. 4 I have shown the line F as constituting a telephone-circuit including the microphone-transmitter T^{111} and battery B^{111}. In all instances it will be understood by those

skilled in the art and without going into further detail that the signal-indicating device R, which is included in the local receiving-circuit, may be any device suitable for the purpose of reproducing the signal initiated in the line F.

I do not limit myself to any of the specific embodiments of my invention herein described, inasmuch as many modifications will

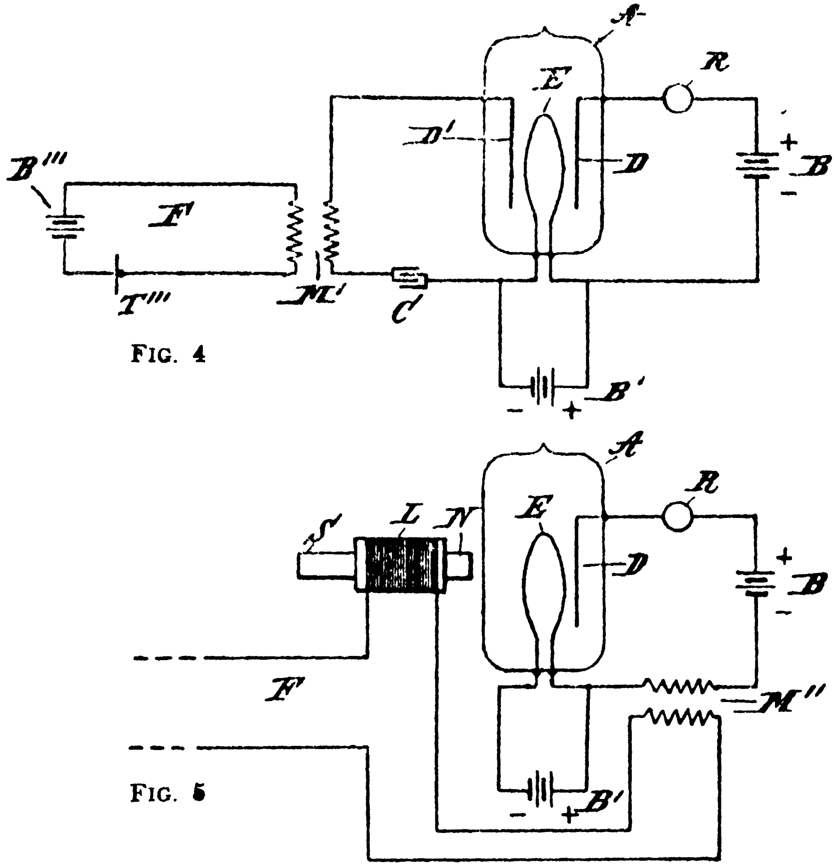


FIG. 4

FIG. 5

Fig. XII*a*.

readily occur to those skilled in the art without departing from the principle of my invention.

I claim—

4. In a device for amplifying electrical currents, an evacuated vessel, three electrodes sealed within said vessel, means for heating one of said electrodes, a local receiving-circuit including two of said electrodes, and means for passing the current to be amplified between one of the electrodes which is included in the receiving-circuit and the third electrode.

5. In a device for amplifying electrical currents, an evacuated vessel inclosing a gaseous medium, means other than the received energy for maintaining said gaseous medium in a condition of molecular activity, means for impressing the currents to be amplified upon said gaseous medium, and a local receiving-circuit having its electrodes sealed within said vessel.

6. In a device for amplifying electrical currents, an evacuated vessel, a heated electrode and two non-heated electrodes sealed within said vessel, the non-heated electrodes being unequally spaced with respect to said heated electrode, a local receiving-circuit including said heated electrode and that one of the non-heated electrodes which has the greater separation from the heated electrode, and means for passing the current to be amplified between the heated electrode and the other non-heated electrode.

In testimony whereof I have hereunto subscribed my name this 17th day of October, 1906.

LEE DE FOREST.

Witnesses:
RALPH POLK BUELL,
SIDNEY WILLIAMS.

UNITED STATES PATENT OFFICE

LEE DE FOREST, OF NEW YORK, N.Y., ASSIGNOR, BY MESNE ASSIGNMENTS, TO DE FOREST RADIO TELEPHONE CO., A CORPORATION OF NEW YORK

SPACE TELEGRAPHY

SPECIFICATION OF LETTERS PATENT NO. 879,532.
PATENTED FEBRUARY 18, 1908 (ABRIDGED)

Application filed January 29, 1907. Serial No. 354,662

To all whom it may concern:

Be it known that I, LEE DE FOREST, a citizen of the United States, and a resident of New York, in the county of New York and State of New York, have invented a new and useful Improvement in Space Telegraphy, of which the following is a specification.

My invention relates to wireless telegraph receivers or oscillation detectors of a type heretofore described in my prior Letters Patent Nos. 824,637, June 26, 1906 and 836,070, November 13, 1906.

The objects of my invention are to increase the sensitiveness of oscillation detectors comprising in their construction a gaseous medium by means of the structural features and circuit arrangements which are hereinafter more fully described.

My invention will be described with reference to the drawings

which accompany and form a part of the present specification, although it is to be understood that many modifications may be made in the apparatus and systems herein described without departing from the principles of my invention.

In the drawings, Fig. 1 represents in diagram a wireless telegraph receiving system comprising an oscillation detector constructed and connected in accordance with the present invention and Fig. 2 represents a space telegraph receiving system having a modified form of oscillation detector connected therein in a manner which constitutes one of the subjects matter of said invention. . . . . . .

D represents an evacuated vessel, preferably of glass, having sealed therein three conducting members, F, *a* and *b*, in Fig. 1 and F, a^1 and *b* in Fig. 2. The conducting member or electrode F is shown as consisting of a filament, preferably of metal, which is connected in series with the battery A or other source of electrical current of sufficient strength to heat said filament, preferably to incandescence. The conducting member *b*, which may be a plate of platinum, has one end brought out to the terminal 3. Interposed between the members F and *b* is a grid-shaped member *a*, which may be formed of platinum wire, and which has one end brought out to the terminal 1. The local receiving circuit, which includes the battery B, or other suitable source of electromotive force, and the signal indicating device T, which may be a telephone receiver, has its terminals connected to the plate *b* and filament F at the points 3 and 4 respectively. The means for conveying the oscillations to be detected to the oscillation-detector, are the conductors which connect the filament F and grid *a* to the tuned receiving circuit and, as shown, said conductors pass from the terminals 2 and 1 to the armatures of the condenser C.

I have determined experimentally that the presence of the conducting member *a*, which as before stated may be grid-shaped, increases the sensitiveness of the oscillation detector and, inasmuch as the explanation of this phenomenon is exceedingly complex and at best would be merely tentative, I do not deem it necessary herein to enter into a detailed statement of what I believe to be the probable explanation. . . . .

By reference to Fig. 1, it will be seen that a similar closed circuit exists between said battery, and the electrode *b* and conducting member *a*. In order to close each of said circuits to the passage of direct current from the aforesaid battery there-through, or to prevent the development of a difference of potential between the members *a* and *b*, or between a^1 and *b*, or to prevent the members *a* or a^1 from receiving an electrical charge from said battery, I insert the condenser C^1 in said otherwise mechanically closed circuit and find that the presence of said condenser produces a great increase in the sensitiveness of the oscillation detector as determined by the very marked increase in the sound produced in the telephone T when said condenser is present over the sounds produced therein under the same conditions when said condenser is not employed.

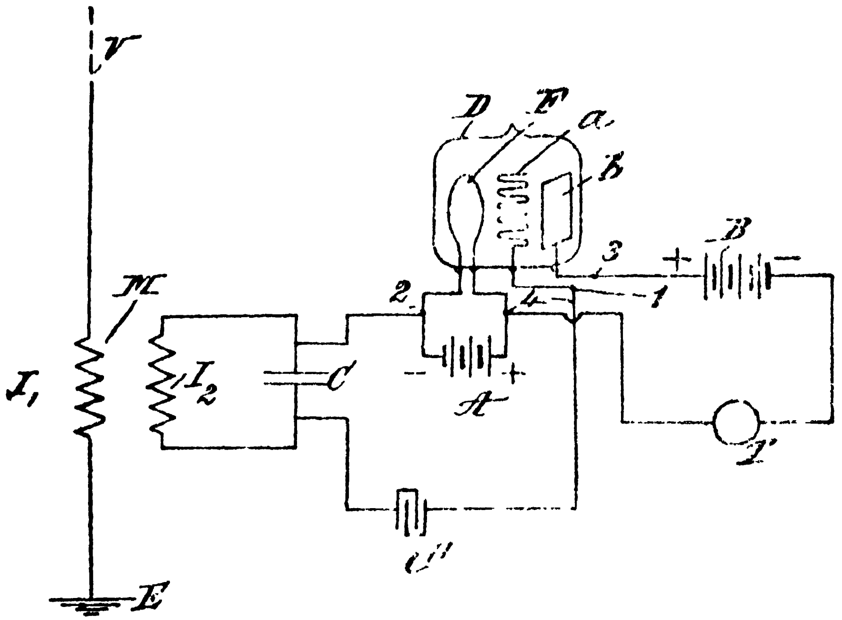


Fig. 1.

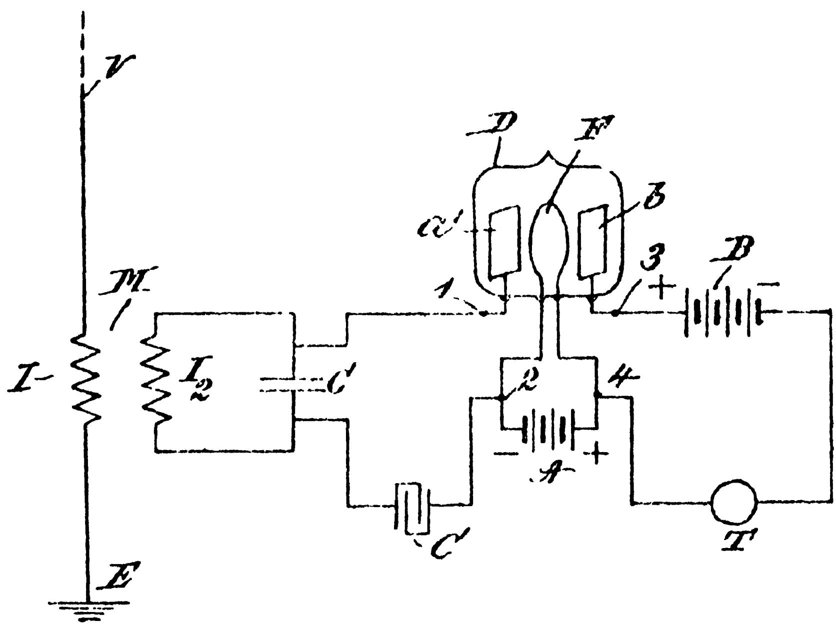


Fig. 2.

Fig. XIII.

It will be understood that the circuit arrangements herein described with reference to the particular forms of audion herein disclosed may with advantage also be employed with various other types of audion.

I claim:

1. An oscillation detector comprising an evacuated vessel, an electrode inclosed therein, means for heating said electrode, a second electrode inclosed within said vessel, a local circuit having its terminals electrically connected to said electrodes, a conducting member inclosed within said vessel and located between said electrodes, and means for conveying the oscillations to be detected to the first mentioned electrode and said conducting member.

2. An oscillation detector comprising an evacuated vessel, two electrodes inclosed within said vessel, means for heating one of said electrodes, and a conducting member inclosed within said vessel and interposed between said electrodes.

3. An oscillation detector comprising an evacuated vessel, two electrodes inclosed within said vessel, means for heating one of said electrodes, and a grid-shaped member of conducting material inclosed within said vessel and interposed between said electrodes.

4. An oscillation detector comprising an evacuated vessel, a filament sealed therein, a source of electrical energy connected in series with said filament, an electrode sealed in said vessel, a local circuit having its terminals connected to said filament and electrode, respectively, said local circuit including a source of electromotive force and a signal-indicating device, a grid of conducting material sealed in said vessel and interposed between said filament and electrode, and means for conveying the oscillations to be detected to said filament and grid.

5. An oscillation detector comprising an evacuated vessel, an electrode inclosed therein, means for heating said electrode, a second electrode inclosed within said vessel, a local circuit having its terminals connected to said electrodes, a conducting member inclosed within said vessel and located between said electrodes, a closed circuit for conveying the oscillations to be detected to said first-mentioned electrode and conducting member, and a condenser in said closed circuit. . . . .

In testimony whereof, I have hereunto subscribed my name this 21st day of December, 1906.

LEE DE FOREST.

Witnesses:

THOMAS I. GALLAGHER,
HANS W. GOETZE.

AUTHOR'S NOTE.—This patent expires on February 18th, 1925.

EXTRACTS FROM THE SPECIFICATION OF BR. PAT. NO. 8821, A.D. 1913

Date of Application, April 15, 1913
Accepted, October 2, 1913

COMPLETE SPECIFICATION

A Receiving Arrangement for use in Wireless Telegraphy and Telephony

(Communicated by Gesellschäft fur Drahtlose Telegraphie m.b.H., of 9 Tempelhofer Ufer, Berlin, in the Empire of Germany, Manufacturers.)[1]

Receiving arrangements for use in wireless telegraphy are known in which vacuum tubes with a glowing cathode and one or more cold anodes are employed for detecting electrical oscillations. However, these known devices have hitherto only utilized the unidirectional conductivity of the gas ionized by the hot electrode in order to transform the electrical oscillations into direct current or into pulsating current of unchanging sign, thus making them suitable for indication by means of a telephone or a direct current instrument.

The object of the present invention is a device for receiving electrical oscillations, for use in wireless telegraphy and telephony, in which the valve action of vacuum tubes is not employed for the detection of the electrical oscillations, but in which vacuum tubes having glowing cathodes serve the purpose of strengthening the electrical oscillations without thereby giving rise to a change in their wave form owing to the valve action. The detection of the electrical oscillations is accordingly not affected by the vacuum tubes themselves as in known devices, but other or separate detectors are employed for this purpose, e.g., thermo-cells or electrolytic rectifiers. . . .

In the arrangements hitherto known the telephone or a sensitive direct current instrument has been inserted in the circuit containing the source of direct current *i*. It is obvious that in such an arrangement the relay action of the tube is practically non-existent because it is well known that electrical oscillations of high frequency cannot directly influence such instruments. For this reason, hitherto, it has been only the comparatively small unidirectional conductivity of such gaseous conducting paths that came into consideration for detecting the oscillations. According to the present invention the relay action of vacuum tubes is utilized and another detector is employed to rectify the oscillations. In the form of the arrangement shown in Fig. 1 this is effected by transferring the strengthened current oscillations, by means of the transformer *k*, to a special receiving circuit, where they are rectified by the detector *l* so that

[1] This is Schloemilch and Von Bronk's invention.

they act on the telephone *m*. In this way the detector gives regular unidirectional current impulses of low frequency, for example, in the case of transmitting regular impulses as in sending devices in wireless telegraphy in which the wave trains are produced at acoustic frequencies, or the detector gives irregular unidirectional current pulsations, also of low frequency, in the case of transmitting speech in telephony.

The impulses or currents of low frequency given by the rectifier can now be further strengthened by similar gaseous conducting paths before they are led to the telephone or other indicating instrument. For this method of operation an especially simple arrangement is obtained, which is very effective in its working, by employing one and the same gaseous path both for strengthening the high frequency oscillations and also for strengthening the low frequency currents.

Fig. 2 shows an example of an arrangement for strengthening by a plurality of gaseous path. Here again *a* is the vacuum tube with the oxide cathode *c*, the anode *d* and the auxiliary anode *e*. The oscillations excited in the coil *g* by way of the aerial conductor *f* are led to the auxiliary anode *e* and cathode *c* in the same manner as in Fig. 1. The strengthened high frequency oscillations then pass into the circuit containing the source of direct current *i* through the cathode *c* and anode *d*, and are transferred therefrom by the aid of the transformer *k* to the detector circuit containing the detector *l*. In this case it is convenient to provide an intermediate circuit *n* tuned to the oscillations. The low frequency impulses or currents furnished by the detector *l* are now led through a transformer *o* to a second tube a^1 having a cathode c^1, anode d^1 and auxiliary anode e^1. They are again strengthened by this tube and the strengthened currents of low frequency are finally led from the circuit containing the source of direct current i^1 through a further transformer *p* to the telephone *m* or other indicating instrument. Obviously further strengthening can be effected by other vacuum tubes.

A double strengthening by means of one and the same tube is obtained in a very simple way by the arrangement shown in Fig. 3. . . . Having now particularly described and ascertained the nature of the said invention and in what manner the same is to be performed, as communicated to me by my foreign correspondents, I declare that what I claim is:—

1. A receiving arrangement for use in wireless telegraphy and telephony, having a gaseous path permanently ionized by a heated cathode influenced by the electrical oscillations, in which the oscillations, strengthened in known manner by an auxiliary current, are by a rectifier made capable of being received by an indicating device.

2. A receiving arrangement as in Claim 1, in which the pulsating currents of comparatively low frequency are again strengthened by similar gaseous paths working with heated cathodes, before said low frequency currents are led to the indicating instrument.

3. A receiving arrangement as in Claim 1, in which the

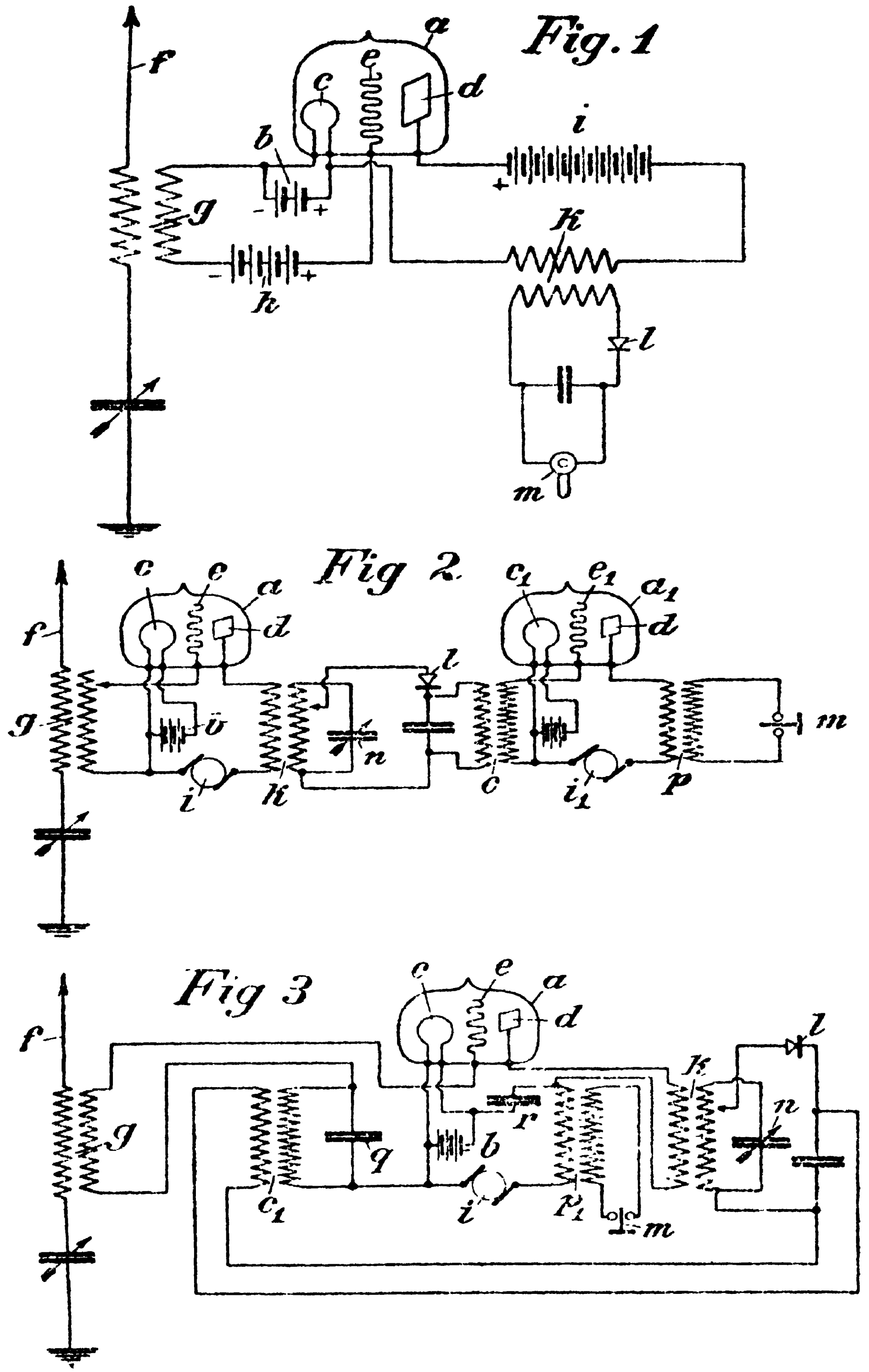


Fig. XIV.

strengthening of the currents of low frequency furnished by the rectifier is effected by the same gaseous path which strengthens the high frequency currents.

4. An arrangement as in Claim 3, in which the low frequency currents from the detector circuit are led through a transformer to the gaseous path, and the secondary coil of this transformer is inserted in the circuit leading the high frequency currents to the gaseous path, the said currents being led to the indicating instrument after strengthening through a second transformer, the primary coil of which is inserted in the circuit connecting the gaseous path and the detector, a condenser being inserted in parallel with the coils of each transformer, said condenser being of low impedance for the high frequency currents.

Dated this 14th day of April, 1913.

W. P. THOMPSON & CO.,
Agents for the Applicant.

COMPLETE SPECIFICATION—SLIGHTLY ABRIDGED—OF BR. PAT. NO. 13,636, A.D. 1913

Date of Application, June 12, 1913
Complete Specification Left, January 12, 1914
Accepted, June 11, 1914

COMPLETE SPECIFICATION

Improvements in Receivers for Use in Wireless Telegraphy and Telephony

We, Marconi's Wireless Telegraph Company, Limited, and Charles Samuel Franklin, Electrical Engineers, both of Marconi House, Strand, London, W.C., do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

It has been shown that an exhausted tube which contains a heated cathode consisting of a strip of metal covered with an oxide and two anodes, one of which is in the form of a plate with holes and which screens the cathode from the other anode, can be used in a wireless receiver for magnifying both the received oscillations and the telephone currents.

According to this invention when such a tube is used for magnifying the received oscillations we make the circuit, in which the magnified oscillations occur, react on the circuit, in which the oscillations to be magnified occur, by coupling these circuits, either electrostatically or electromagnetically, to a certain degree.

If the coupling be too strong, the tube will be unstable and will itself tend to produce oscillations, but there is a certain critical strength of coupling below which the tube is unable to maintain oscillations. At a coupling a little below this critical strength the tube and circuits are stable but act while receiving oscillations as though the resistance in the circuits was very small.

The result is that the damping of the receiving system can be reduced to any required degree and the tuning of the system is made very sharp.

The accompanying diagram shows a scheme of connections to obtain this result. *v* is an exhausted tube containing a cathode *k*,

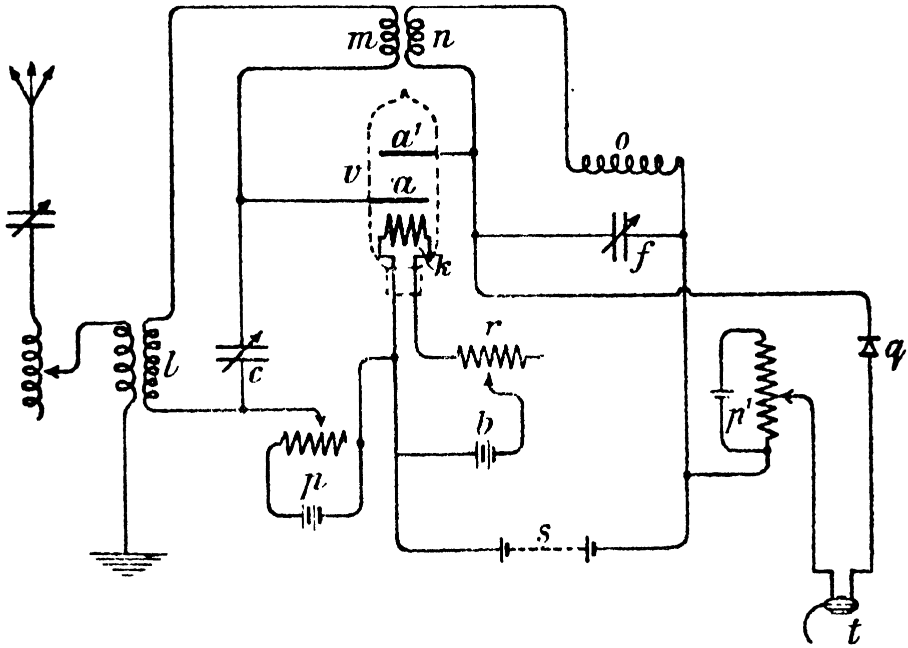


Fig. XV.

which is preferably a metal strip covered with an oxide, and is heated by a battery *b* through a resistance *r*. . . . .

The anode a^1 is connected to a circuit containing inductances *n* and *o* and a condenser *f* which are adjustable and the other side of the condenser is connected through a battery *s*, the E.M.F. of which may be about 200 volts, to the cathode *k*. Across the condenser *f* is connected a rectifier *q*, potentiometer p^1, and a telephone or detector *t* for detecting the oscillations in the circuit *n o f*.

Magnified oscillations occur in the circuit *n o f* and when there is no coupling between *m* and *n*, and all the circuits are tuned, the valve produces in this circuit oscillations which are similar in frequency and damping to the oscillations in the circuit *l m c*, but of much greater intensity.

By coupling the circuits together by means of the coils *m* and *n* the magnified oscillations in circuit *n o f* may be made to sustain the oscillations in the circuit *m l c* and the system then produces continuous oscillation; if however the coupling is adjusted so that the system just refuses to oscillate it will be found that the system acts like a circuit of very low resistance and shows very sharp tuning.

The above circuits are arranged for high frequency oscillations but obviously a similar circuit may be arranged for tuning to the spark frequency of a wireless telegraph transmitter or to the note obtained in a wireless telegraph receiver when using the interference method of receiving continuous oscillations or generally for any case in which sharp tuning is required.

By adjusting the couplings the system can be made to act as a circuit having any desired decrement down to practically zero.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A receiving system for electrical oscillations which contains a valve for magnifying the oscillations and which is so arranged that the circuit in which are set up the magnified oscillation reacts on the circuit in which occur the oscillations to be magnified substantially as described.

2. A receiving system for electrical oscillations substantially as described with reference to the drawing.

Dated this 11th day of January, 1914.

CARPMAEL & CO.,
Agents for Applicants,
24 Southampton Buildings, London, W.C.

UNITED STATES PATENT OFFICE

EDWIN H. ARMSTRONG, OF YONKERS, NEW YORK

WIRELESS RECEIVING SYSTEM

SPECIFICATION OF LETTERS PATENT NO. 1,113,149.
PATENTED OCTOBER 6, 1914 (ABRIDGED)

Application filed October 29, 1913. Serial No. 797,947

To all whom it may concern:

Be it known that I, EDWIN H. ARMSTRONG, a citizen of the United States, residing at 1032 Warburton Avenue, Yonkers, county of Westchester, State of New York, have invented certain new and useful Improvements in Wireless Receiving Systems; and I do hereby declare the following to be a full, clear, and exact description of the

Fig. 1.

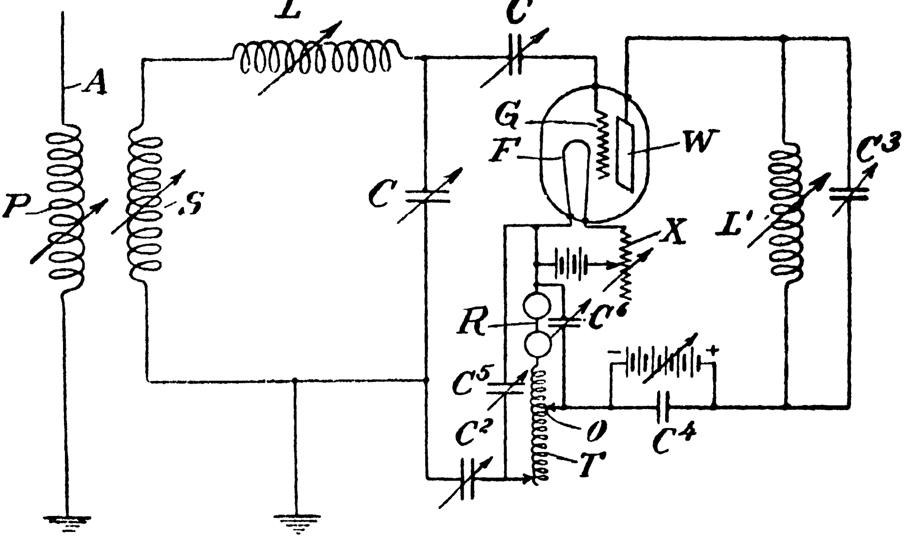


Fig. 2.

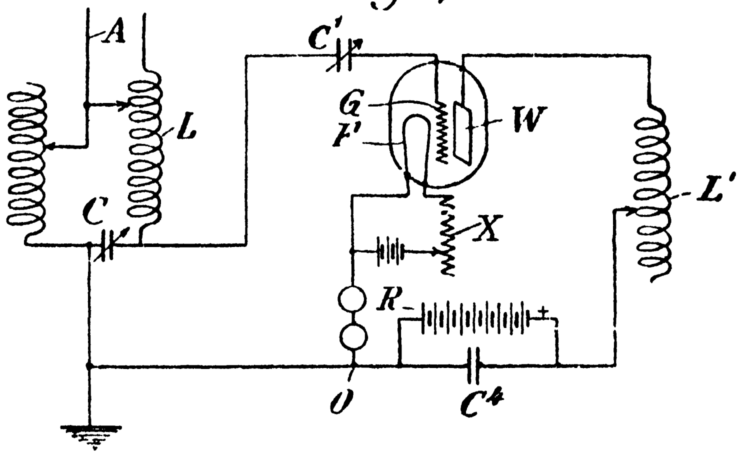


Fig. XVI.

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invention, such as will enable others skilled in the art to which it appertains to make and use the same.

The present invention relates to improvements in the arrangement and connections of electrical apparatus at the receiving station of a wireless system, and particularly a system of this kind in which a so-called " audion " is used as the Hertzian wave detector; the object being to amplify the effect of the received waves upon the current in the telephone or other receiving circuit, to increase the loudness and definition of the sounds in the telephone or other receiver, whereby more reliable communication may be established, or a greater distance of transmission becomes possible. To this end I have modified and improved upon the arrangement of the receiving circuits in a manner which will appear fully from the following description taken in connection with the accompanying drawings. As a preliminary, it is to be noted that my improved arrangement corresponds with the ordinary arrangement of circuits in connection with an audion detector to the extent that it comprises two interlinked circuits; a tuned receiving circuit in which the audion grid is included, and which will be hereinafter referred to as the " tuned grid circuit," and a circuit including a battery or other source of direct current and the " wing " of the audion, and which will be hereinafter referred to as the " wing circuit." As is usual, the two circuits are interlinked by connecting the hot filament of the audion to the point of junction of the tuned grid circuit and the wing circuit. I depart, however, from the customary arrangement of these circuits in a manner which may, for convenience of description, be classified by analysis under three heads; firstly, the provision of means, or the arrangement of the apparatus, to impart resonance to the wing circuit so that it is capable of sustaining oscillations corresponding to the oscillations in the tuned grid circuit; secondly, the provision of means supplementing the electrostatic coupling of the audion to facilitate the transfer of energy from the wing circuit to the grid circuit, thereby reinforcing the high frequency oscillations in the grid circuit, and thirdly, the introduction into the wing circuit of an inductance through which the direct current of the wing circuit flows, and which is so related to the grid circuit that the maintaining electromotive-force across the terminals of the inductance due to reduction of the direct current, is effective in the tuned grid circuit to increase the grid charge and consequently to further reduce the current in the wing circuit and in the telephones. By a further extension of this idea, the effect of the maintaining electromotive-force upon the grid current may be augmented by the use of a transformer in a manner which will be understood from the following description.

Fig. 1 illustrates the arrangement and connection of apparatus with which I have thus far obtained the best results and which embodies in combination the several features of improvement which I have invented or discovered. Fig. 2 represents a like arrangement with the exception that there is no transformer for augmenting the effect of the maintaining electromotive-force, and several condensers,

Fig. 3,

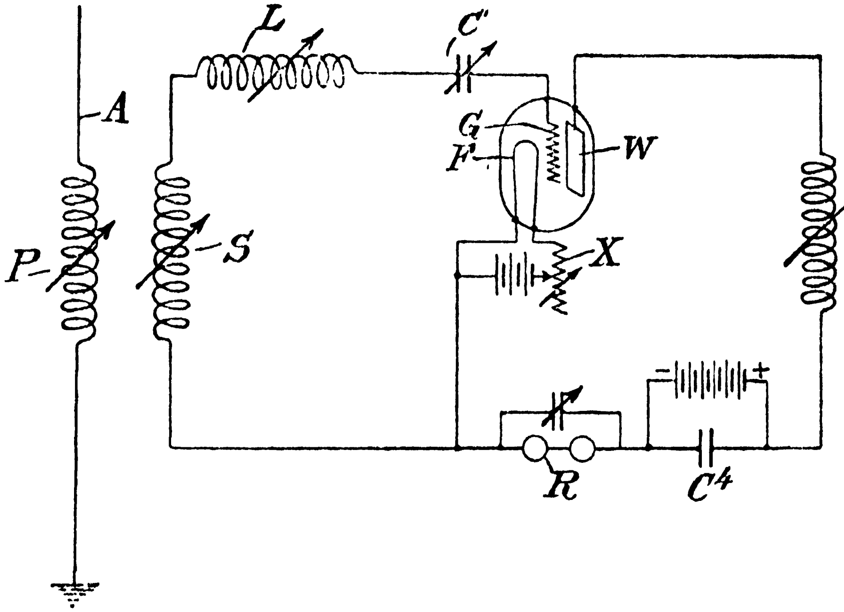

Fig. 4,

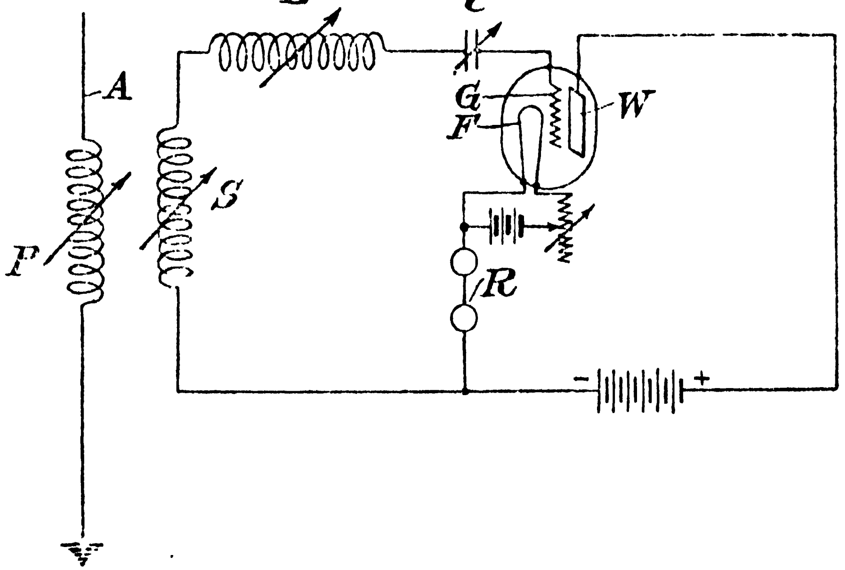

Fig. XVI*a*

which may advantageously be employed but which are not essential, are eliminated. Fig. 3 illustrates an arrangement in which the advantages of my invention are only partially present, the inductance which produces the maintaining electromotive-force effective on the tuned grid circuit being eliminated. Fig. 4 illustrates an arrangement in which inductance, in this case the inductance of the telephones, is employed for producing the maintaining electromotive-force effective on the tuned grid circuit, but the wing circuit is not resonant. Fig. 5 illustrates an arrangement in which an inductance replaces the telephones in that portion of the connections which is common to the two circuits, and the telephones are put in the wing circuit, and Fig. 6 illustrates an arrangement in which a double winding transformer is used, the primary being located in the wing circuit. . . . I find that with such an arrangement of apparatus, and by properly adjusting the reactances, signals which are scarcely audible with the ordinary audion connection can be amplified to a point where they are too strong for, and "paralyse" the most stable audions that I have been able to obtain. . . . . . .

It will be observed, that this capacity of the telephone cords in Figs. 2 and 4, and likewise the capacity C^5 in Fig. 5 and the distributed capacity of the transformers in Figs. 1 and 6, is in each case common to the grid circuit and the wing circuit and constitutes an electrostatic coupling facilitating the transfer of energy from the wing circuit to the grid circuit and increasing the effect upon the grid of high frequency pulsations in the wing circuit. This effect occurs whether the wing circuit is tuned or not, but obviously the transfer of energy is increased by tuning the two circuits alike. I have discovered, however, that the beneficial effect may be still further increased by the interposition of a transformer in such a way as to increase the effect of the maintaining electromotive-force due to the reduction of current through the telephone receivers, and such a transformer is shown at T in Fig. 1. . . . It will be understood from what has been said that the ratio of transformation of the transformer should be adjusted to get the maximum signals without causing the audion to generate oscillations. . . . . . .

From what has been said, it will be understood that the inductance of the telephones may be utilized as the generator of the maintaining electromotive-force by inserting the telephones in the connections common to the two circuits, as shown in Figs. 1, 2 and 4; but a like result will be obtained by locating the telephones in the wing circuit as indicated in Fig. 5, and placing a suitable inductance as L^2 in that portion of the connections which is common to the two circuits. . . . .

The way to tune this set is to cut out L^1, set C^1 at ·00005 microfarads, and then adjust P, S, L and C as in the ordinary audion set until signals are strongest. The inductance L^1 is then gradually cut in and the strength of the signals will increase many times until a point is reached where the signals lose distinctness and there is a loud hiss in the telephones. This indicates that the audion is

Fig. 5,

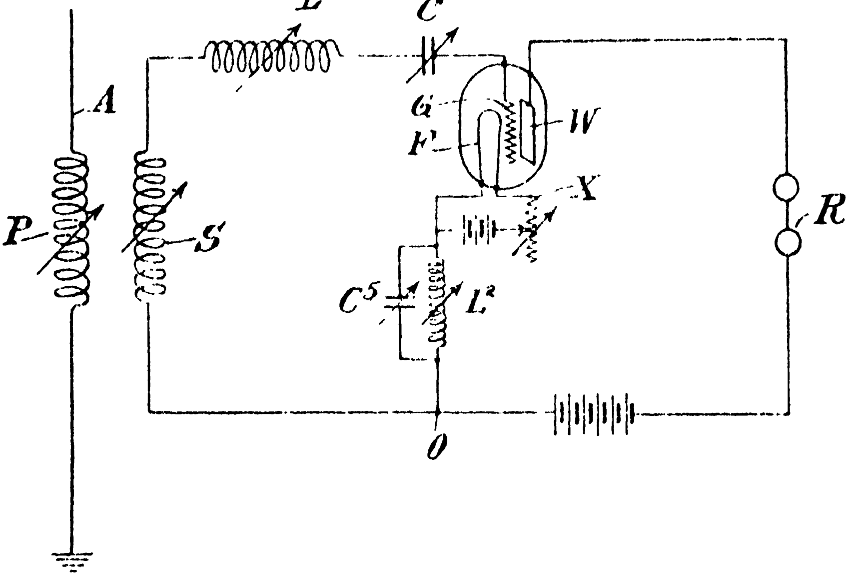

Fig. 6

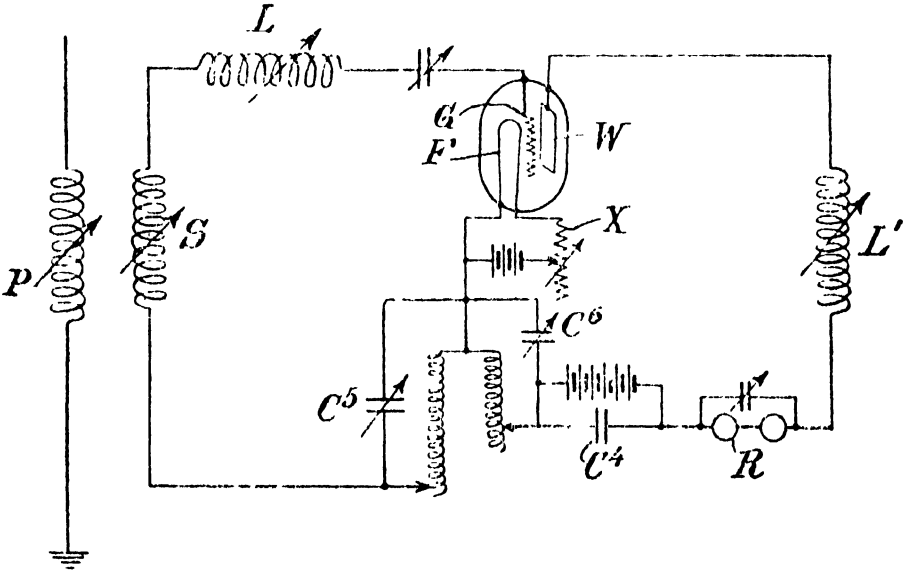

Fig. XVIb.

generating high frequency oscillations in the grid and wing circuits, and the inductance L^1 should be set at a point just below that at which this occurs. If there is no hiss as L^1 is increased, and the signals pass through a maximum of strength and begin to fall off, then L^1 should be set at the point of maximum strength of signals and C^1 should be increased to a point just below that at which the hiss appears. Under these circumstances, the increase of C^1 will be accompanied by an increase of the strength of the signals, the maximum strength being obtained in each case just below that point at which the audion begins to act as a generator of high frequency oscillations.

I find that the capacity required to by-pass the oscillations about the inductance which is common to the two circuits, and about the transformer, if the transformer is used, is relatively small; and when the telephone receivers are used as the inductance at this point, the capacity of the telephone cords is sufficient. . . . . . .

Having thus described my invention, what I claim is:

1. An audion wireless receiving system having a resonant wing circuit interlinked with a resonant grid circuit upon which the received oscillations are impressed, the resonant grid circuit having a capacity so related to the grid as to receive and retain the charge which accumulates thereon.

16. An audion wireless receiving system having a resonant wing circuit interlinked with a resonant grid circuit upon which the received oscillations are impressed, and means supplementing the coupling of the audion to facilitate transfer of energy from the wing circuit to the grid circuit, whereby the effect upon the grid of high frequency pulsations in the wing circuit is increased.

17. An audion wireless receiving system having a wing circuit interlinked with a resonant grid circuit upon which received oscillations are impressed and an electrostatic coupling between the circuits supplementing the coupling of the audion to facilitate transfer of energy from the wing circuit to the grid circuit, whereby the effect upon the grid of high frequency pulsations in the wing circuit is increased. . . . .

In testimony whereof I affix my signature, in presence of two witnesses.

EDWIN H. ARMSTRONG.

Witnesses:

William H. Davis,
John C. Pennie.

Author's Note.—The status of this patent must be considered in the light of the judgment quoted on page 46.

EXTRACTS FROM THE COMPLETE SPECIFICATION OF BR. PAT. NO. 28,413. A.D. 1913

Date of Application, December 9, 1913
Complete Specification Left, July 8, 1914
Accepted, December 9, 1914

COMPLETE SPECIFICATION

IMPROVEMENTS IN RECEIVERS FOR USE IN WIRELESS TELEGRAPHY

We, MARCONI'S WIRELESS TELEGRAPH COMPANY, LIMITED, and HENRY JOSEPH ROUND, both of Marconi House, Strand, London, W.C., Electrical Engineers, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to improvements in receivers for wireless telegraphy in which a vacuum tube of the type having a hot filament, a grid and a third electrode is employed.

According to this invention we connect across the hot filament and the third electrode, and in addition to the ordinary telephone and battery, an oscillation circuit which is tuned to a frequency slightly different from that of the received oscillations. By suitably adjusting the circuits, signals produced by continuous waves can be heard in the telephones. If the capacity between the grid and the third electrode is insufficient, a small condenser may be connected across the grid and the third electrode, or the oscillation circuit may be made to interact with the aerial or with an intermediate oscillation circuit by so arranging the circuits that there is mutual inductance between them. . . . .

Our invention is illustrated in the accompanying drawing.[1] .

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. In a receiver for continuous waves having a vacuum tube containing a hot filament, a grid and a third electrode, an oscillation circuit tuned to a frequency slightly different from that of the received waves and connected across the filament and the third electrode substantially as described.

2. A receiver as claimed in Claim 1 in which the oscillation circuit is caused to interact with the aerial or with an intermediate circuit substantially as described.

3. A vacuum tube containing a hot filament, a grid formed as a closed cylinder completely surrounding the filament and a third electrode in the form of a cylinder surrounding the grid substantially as described.

[1] P. 169.

4. Wireless telegraph receivers substantially as described with reference to the drawing.

Dated the 8th day of July, 1914.

CARPMAELS & CO.,
Agents for Applicants.

EXTRACTS FROM THE AMENDED SPECIFICATION OF BR. PAT. NO. 252. A.D. 1914

Date of Application, January 5, 1914
Accepted, August 19, 1915

COMPLETE SPECIFICATION (AMENDED)

Improvements in and Relating to Relay Arrangements for Alternating Currents

We, Graf Georg von Arco and Dr. Alexander Meissner, both of Tempelhofer Ufer 9, Berlin, in the Empire of Germany, Engineers, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The present invention relates to a new arrangement of electrical relays in which the means exerting the relay action essentially consist of an ionized gas. A specially suitable form of this relay consists of a glass vessel wholly or partially evacuated or filled with gas or vapour at a low pressure, which vessel contains a heated oxide cathode and one or more anodes. The cathode rays streaming from the oxide cathode effect an ionization of the gas so that a permanent current path is made from the anode to the cathode. The currents to be strengthened may be led to the heated cathode and an auxiliary anode. The strengthened currents are then developed in the current circuit, being led through the cathode and main anode, by which means the increased energy of this current is obtained from the source of current furnishing permanent current. In another form which resembles the known Braun's cathode ray tube, the oscillations to be strengthened are led to two special electrodes between which are passed streams of ions from anode to cathode.

Since the active element of this relay has no mass, in contradistinction to mechanically operating relays, these relays are especially well suited for such alternating currents in which the current variations take place very rapidly and for such purposes in which an exact repetition of all changes is desired, for example, for strengthening microphone currents and especially for the strengthening and generation of the rapid oscillations in wireless telegraphy and telephony.

The present invention relates to the arrangement of the current

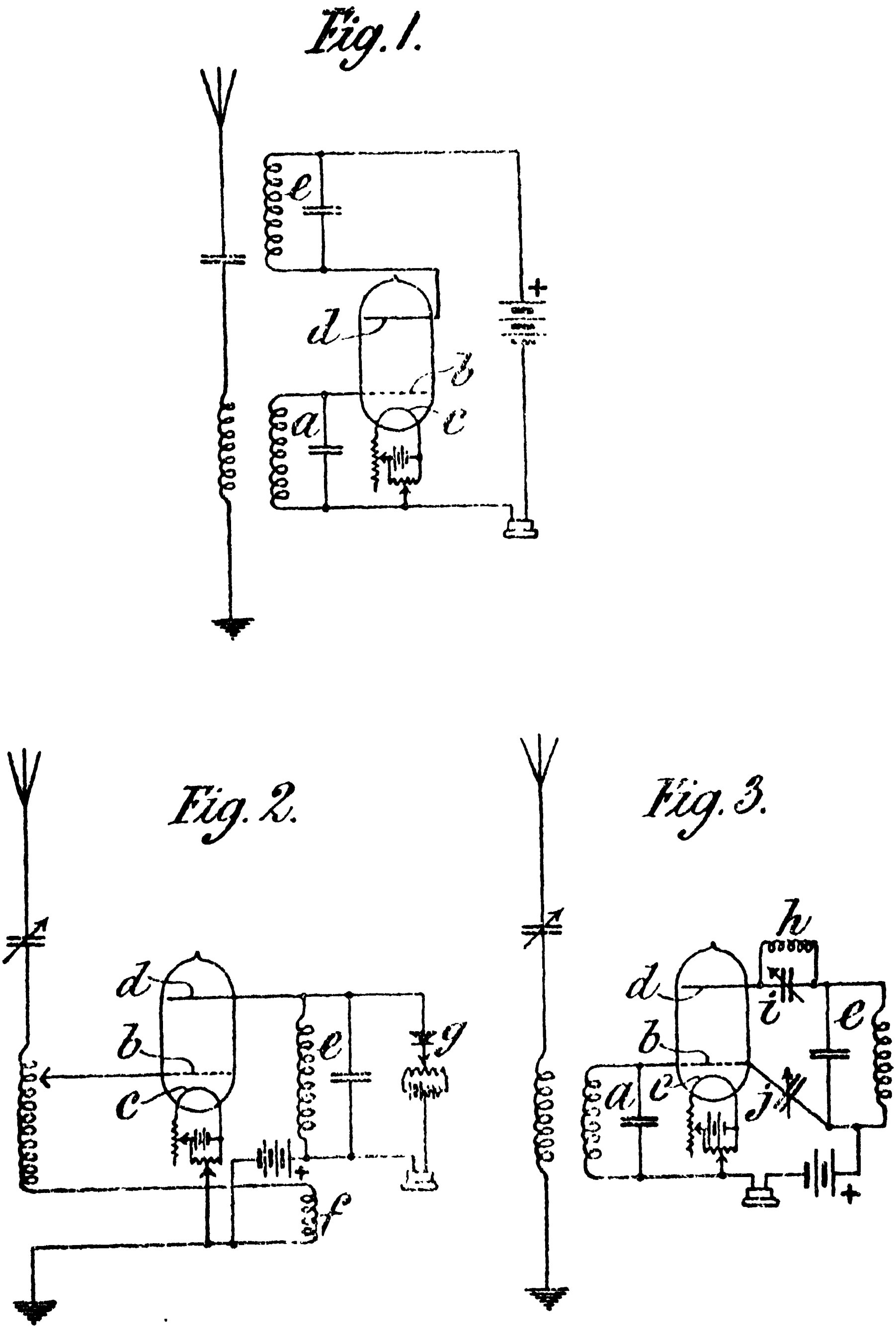

Fig. XVII. Round's Br. Pat. 28,413/13 (see p. 167.)

circuit operating with the relay. This arrangement essentially consists in that the circuit, which is connected to the secondary path of the relay, i.e., to which the strengthened relay current is led, is again connected with the circuit carrying the original current and connected with the primary path of the relay, so that the energy furnished by the relay again passes into the relay with unchanged frequency.

By this return coupling a considerable improvement of the relay action is attained, i.e., a strengthening of weak currents which surpasses that attainable in known arrangements. At the same time the return passage of the energy in this arrangement renders possible a mode of action of this relay which is quite novel. Thus if a relay so arranged is connected with an electric system capable of oscillation, it is then possible to maintain a permanent condition of oscillation in the system. More particularly for wireless telegraphy and telephony this is of very great importance since by this means it is possible for the first time to generate undamped oscillations possessing an absolutely constant amplitude.

The new arrangement further renders possible the formation of specially active receiving arrangements by allowing the relays so arranged to co-operate with a receiving arrangement in a common detector or indicator circuit. If the oscillations generated by the relay are given, in a manner known *per se*, a frequency somewhat diverging from the oscillations received, then by means of an ordinary receiving apparatus it is possible to receive undamped oscillations in the form of completely pure tones, produced by interference of the two oscillations. By the strengthening which is thus possible oscillations can be received of such small intensity as can no longer be rendered perceptible by other means; in this way it is possible to magnify the range of wireless stations. . . . .

Fig. 6 represents a simple exciting arrangement. . . .

The generation of oscillations also takes place when using an alternating current of low period, and since the tubes as mentioned above possess a valve action this generation always takes place in the half period in which there is a positive potential at the anode 3. In this way trains of oscillations are obtained which are separated by pauses of the length of a half period of the alternating current supply.

In order to be able to generate uninterrupted oscillations with an alternating current supply, it is preferable to employ two relays connected in parallel in such manner that during one half period the alternating current supplied operates one relay while during the other half period the reverse is the case. . . . .

The energy which can be generated by this generator can attain fairly considerable values so that it is possible indeed to employ this generator for transmitting purposes in wireless telegraphy. This excitation arrangement is particularly suitable however for receiving very weak currents when producing sounds in that the oscillations received are caused to interfere with the oscillations generated in the above manner at the receiving station. . . . .

Fig.5

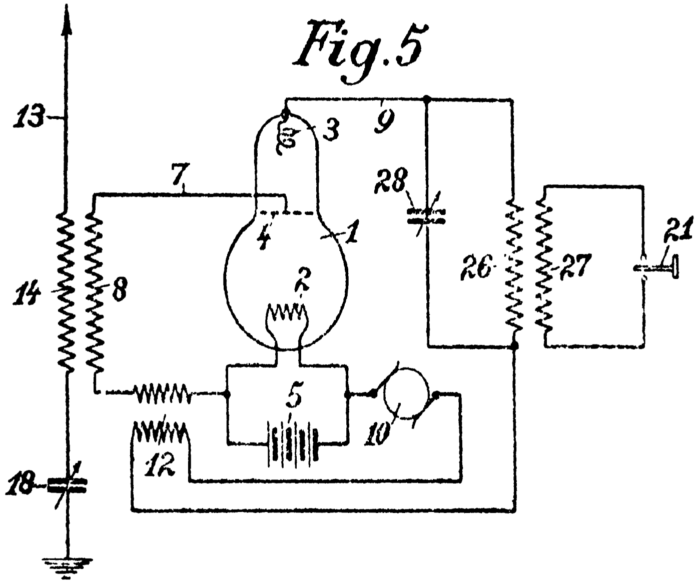

Fig.6

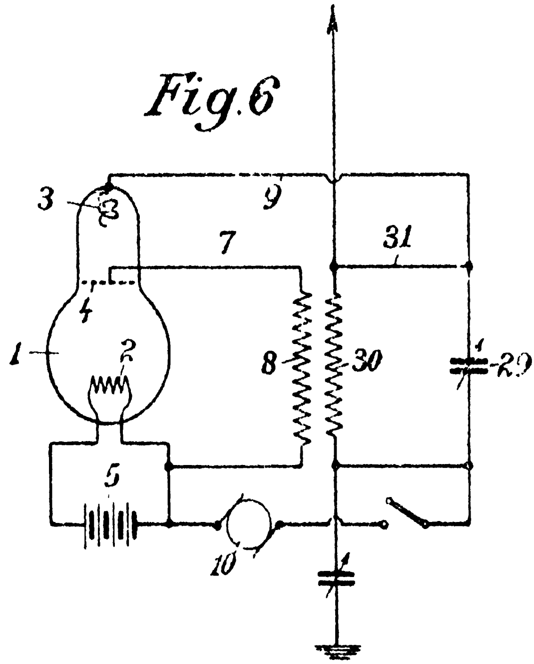

Fig. XVIII.

If in this interference arrangement the relay acting as generator is supplied with alternating current in the manner described, it is convenient in order to obtain a pure sound to choose the frequency of this alternating current supply comparatively low so that within one alternation a number of beats takes place.

The strengthening action of the arrangement makes it possible to detect easily even very weak signals from very distant sending stations which signals are otherwise scarcely perceptible, but even in those cases in which the incoming signals are in themselves sufficiently strong for detection, this arrangement makes it possible to secure other advantages which consist in a very thorough selection from atmospheric and other disturbances. . . . . . .

Experiments with this receiving arrangement have shown that it is possible to produce easily audible sounds by the interference arrangement when two oscillations are made not approximately equal, but considerably different from one another. This is the case when the oscillations generated at the receiving place are given a frequency which is either near to an over-tone or an under-tone of the oscillations received which therefore differs therefrom by an approximate multiple. This procedure is of special advantage in the case of receiving damped oscillations generated by sparks.

The interference arrangement above described can also be employed several times in series in such manner that the interference oscillation first generated co-acts with a second oscillation generator which generates a current of diverging frequency again causing interference. In this way it is possible with certainty to remove all disturbances caused by atmospheric discharges or other causes. . . . .

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that we do not claim the inventions claimed in Specifications Nos. 13,636 and 28,413 of 1913 and No. 24,231 of 1914, but what we claim is:—

1. A relay arrangement for alternating currents particularly suitable for wireless telegraphy and telephony having an electric relay operating by means of an ionized gas path in which the current strengthened by the relay is led with unchanged frequency directly or indirectly to the primary circuit of the relay again, so that the whole of this current or a part thereof repeatedly passes through the relay and is thus further strengthened.

2. An arrangement as in Claim 1 in which the primary current to be strengthened is directly or indirectly led both to the relay and also to the detector circuit or the indicating instrument.

3. An arrangement as in Claims 1 or 2 in which the indicating instrument or the detector circuit is directly coupled with the antenna or the telephone line.

4. An arrangement as in any of the preceding claims in which the indicating instrument (telephone) is directly connected (for example by means of a transformer) with the circuit coupled back to

the primary circuit of the relay and receiving the strengthened relay current.

5. An arrangement as in Claim 4 in which a regulable alternating current resistance (condenser or choking coil) is connected in parallel

Fig. 9

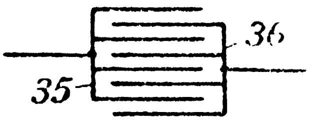

Fig. 10

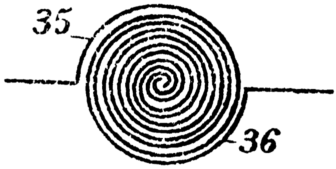

Fig. 12

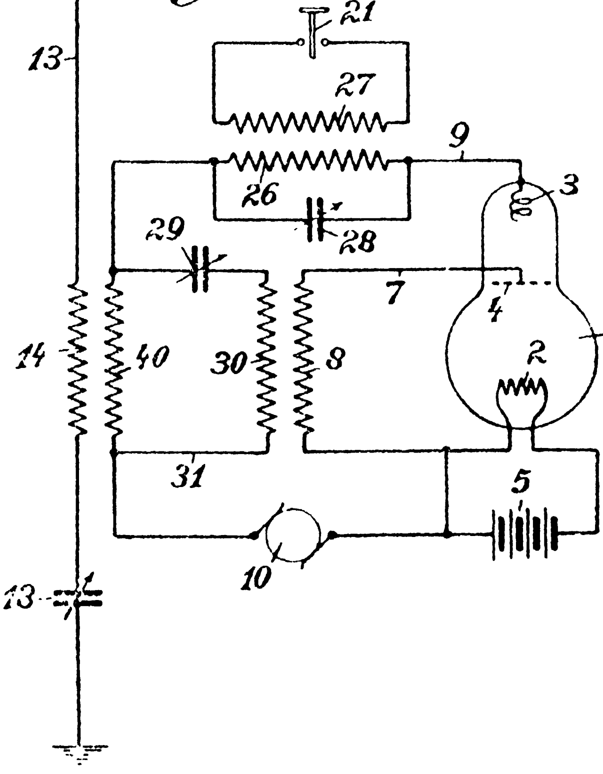

Fig. XVIII*a*.

or in series with the telephone transformer, for regulating the reception of energy by the indicating instrument.

6. An arrangement as in Claim 1 in which a closed adjustable oscillation circuit is connected with the primary current circuit or the secondary current circuit of the relay.

7. An arrangement as in Claim 6 in which the closed oscillation circuit is connected both with the side of the relay taking weak current (primary) and that giving strengthened current (secondary), so that the initial oscillations excited in the oscillation circuit are strengthened by the relay and will be maintained.

8. An arrangement in which a high tension alternating current is employed to supply the oscillation generator as in Claim 7.

9. An arrangement as in Claim 8 in which two relays are connected in parallel with the source of alternating current in such a manner that the anode of one and the cathode of the other are always at the same pole of the source of alternating current so that both relays alternately operate corresponding to the half periods of the alternating current, thus making the generation of oscillations continuous.

10. An arrangement as in Claims 7, 8 or 9 in which the return coupling of the oscillation circuit with the relay is effected through two special auxiliary electrodes placed opposite to one another in the relay, between which electrodes passes the stream of ions flowing from the cathode to the anode.

11. A relay adapted for use in an arrangement as claimed in Claim 10 having two auxiliary electrodes of comb, spiral or the like shape arranged inter-engaging, for the purpose of strongly affecting the stream of ions.

12. In an arrangement as claimed in Claims 7 to 11, a relay having the cathode material of tungsten, tantalum, osmium or carbon without a coating of oxide so that it is possible to obtain a higher load and a greater utilization of the energy of the relay in generating oscillations.

13. An arrangement as claimed in any of the preceding claims for receiving electric oscillations in which the relay connected by return coupling with a closed oscillation circuit, and thus operating as an oscillation generator, and a receiving antenna, act in common on a receiving apparatus comprising a detector and indicating instrument, and in which the frequency of the oscillations generated due to this relay is made approximately equal to the frequency of the oscillations received, in order to strengthen the oscillations received by interference and to make them perceptible as pure and readily audible sounds.

14. An arrangement as in Claim 13 in which when the relay is supplied by alternating currents, the frequency of the alternating current supply is made low in comparison to the number of oscillations of the beats desired, to obtain pure sounds.

15. An arrangement as in Claim 13 in which the coupling between the antenna and the receiving system is made as loose as possible in order to diminish the action of atmospheric disturbances on the receiving apparatus.

16. An arrangement as in Claim 13 in which the frequency of the oscillations generated by the relay is variably regulated to an approximate multiple of the frequency of the oscillations received.

17. An arrangement as in Claim 13 in which several relays acting as oscillation-generators each connected with a detector circuit, are employed in series for causing interference action and in which the indicator (telephone) is first connected with the last relay arrangement in order to render the receiving perceptible.

18. An arrangement as in Claim 1 in which the relay is connected with two closed oscillation circuits tuned to different frequencies.

19. An arrangement as in Claim 1 for receiving electric oscillations in which a relay connected with a closed oscillation circuit by return coupling and acting as a generator of oscillations is coupled with a second closed oscillation circuit, tuned to an audible frequency, and with the antenna, in such a manner that the interference produced by infringement of waves, between the oscillation of the first circuit and the oscillation of the antenna, influences the second oscillation circuit so that the signals are perceptible by changes of intensity or sound of the permanent sound produced.

20. An arrangement as in Claim 19 in which an acoustic or electric resonator co-acts with the indicator in such a manner that essentially only the sound of the signal is perceptible in the indicator.

21. A relay arrangement for alternating currents substantially as described and illustrated with reference to the accompanying drawings Figs. 1 to 8 and Figs. 11 and 12.

Dated this 3rd day of January, 1914.

W. P. THOMPSON & CO.

UNITED STATES PATENT OFFICE

ELIHU THOMSON, OF SWAMPSCOTT, MASSACHUSETTS, ASSIGNOR TO THE THOMSON-HOUSTON ELECTRIC COMPANY, OF CONNECTICUT

Method of, and Means for Producing Alternating Currents

SPECIFICATION FORMING PART OF LETTERS PATENT NO. 500,630, DATED JULY 4, 1893 (ABRIDGED)

Application filed July 18, 1892. *Serial No.* 440,698. (*No model*)

To all whom it may concern:

Be it known that I, Elihu Thomson, a citizen of the United States, residing at Swampscott, in the county of Essex and State of Massachusetts, have invented a certain new and useful Improvement in Methods of and Means for Producing Alternating Electric Currents, of which the following is a specification.

The present invention relates to methods of and apparatus for

obtaining alternating currents from a continuous current source or from a source in which the currents are intermittent or from a source in which the potential is sustained during a period more or less great.

My invention is applicable particularly to obtaining currents of and effects of high frequency alternations from continuous current lines or sources. The frequencies obtained can be adjusted or varied. Thus from a five hundred volt supply circuit I may obtain alternating current effects the frequency being, say, ten thousand, twenty thousand, thirty thousand, fifty thousand per second, or more. I may also obtain inductively from the alternating currents of a desired frequency, other

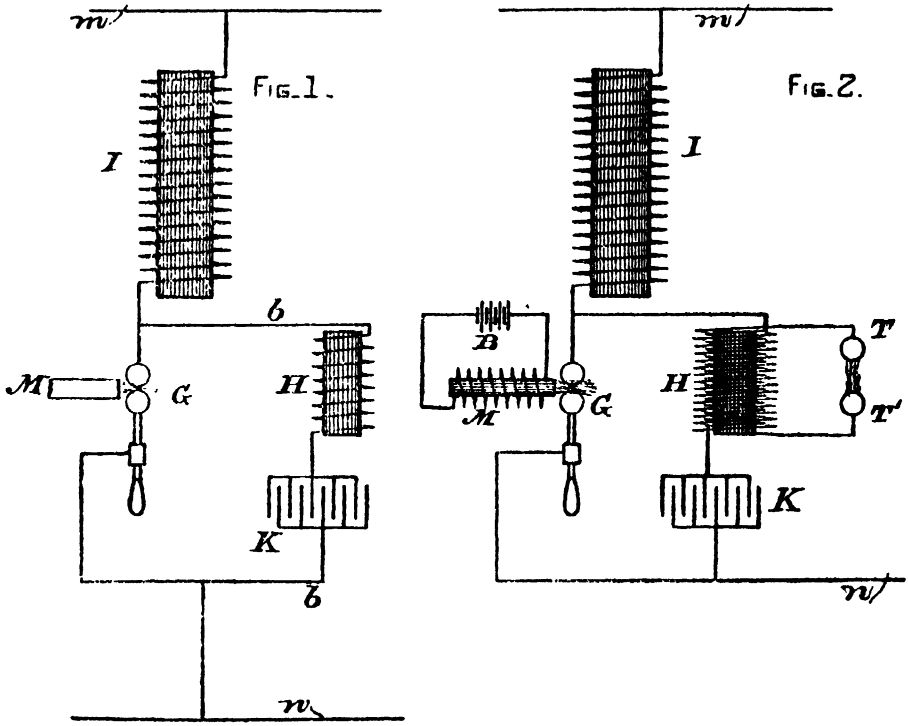

Fig. XIX.

alternating currents (by transformers or condensers in the ordinary way), and may employ such currents for any such purposes for which alternating impulses are applicable.

In Fig. 1 is a diagram showing the features of my invention. Fig. 2 is another diagram showing some additional features. . . .

What I claim as new, and desire to secure by Letters Patent, is—

7. The method of obtaining high frequency currents from continuous currents, consisting in establishing a circuit in which rapid current changes cannot easily take place, and rupturing said circuit at suitable terminals bridged by a condenser, with inductive devices or self-induction coils of wire in said bridge, the capacity and

self-induction in such bridging path together with the spark gap or rupture distance being adjusted or adjustable, substantially as set forth.

8. The method of obtaining high frequency currents from continuous currents, consisting in establishing a circuit in which rapid current changes cannot easily take place, and rupturing said circuit by a magnetic field at suitable terminals bridged by a condenser, with inductive devices in said bridge, substantially as described.

9. The method of obtaining from continuous currents or currents tending, through self-induction or otherwise, to remain unchanged, or to resist sudden change of value, high frequency alternating currents of desired periodicity consisting in bridging by determinate capacity of condenser and a determinate self-induction coil or circuit, a spark gap in said continuous current circuit, said spark gap being adjusted and arranged so as to respond to the desired frequency, substantially as set forth. . . . .

In witness whereof I have hereunto set my hand this 13th day of July, 1892.

ELIHU THOMSON.

Witnesses:
JOHN W. GIBBONEY,
ALEC F. MACDONALD.

EXTRACT FROM COMPLETE SPECIFICATION OF BR. PAT. NO. 21,629, A.D. 1900

Date of Application, November 29, 1900
Complete Specification Left, August 29, 1901
Accepted, November 23, 1901

COMPLETE SPECIFICATION

IMPROVEMENTS IN AND CONNECTED WITH MEANS FOR THE CONVERSION OF ELECTRICAL ENERGY, DERIVED FROM A SOURCE OF DIRECT CURRENT, INTO VARYING OR ALTERNATING CURRENTS

I, WILLIAM DU BOIS DUDDELL, of 47 Hans Place, London, S.W., Electrical Engineer, do hereby declare the nature of this invention and in what manner the same is to be performed to be particularly described and ascertained in and by the following statement:—

This invention relates to the conversion of electrical energy derived from a source of direct current, into varying or alternating currents of sympathetic or controllable periodicity, and has for its object the provision of a method and means, by which such conversion may be effected without the employment of moving contacts; the

resulting current being so sympathetic as to its variations or alternations that it may be utilized to reinforce an existing varying or alternating current, or the periodicity of its alternations may be determined by utilizing known means having self-induction and capacity; and this invention has for its further object the adaptation of such a converted sympathetic current to purposes of practicable utility, such as the reinforcement of the energy of an already existing varying current, as a telephone current, so as to increase the loudness of speech, or the distance to which speech can be transmitted; and the reinforcement of telegraph currents; and for the production of alternating currents; and for the indication of frequency or its variations under certain conditions hereinafter to be defined; and for like purposes. . . . .

I can use as my converting device, the electric arc between solid carbon or other electrodes; and other gaseous conductors, such as vacuum tubes, exhausted to a suitable pressure, and containing suitable gases or vapours; or metallic oxides or salts, or the mixtures of any of these such as a filament of the Nernst lamp; or any other conductors belonging to the class of electrolytic conductors, which fulfil the above defined necessary condition.

I have found that when such a converting device is made to form part of a circuit connected to the source of direct current energy, I can obtain in a shunt circuit between the terminals of such converting device a current which is sympathetic, as to its variations or alternations, to any existing varying or alternating currents flowing in the circuit, which it will therefore reinforce.

Or, I can obtain in the shunt circuit an alternating current of any required frequency, which frequency is determined by the self-induction, capacity, and resistance of that shunt circuit as hereinafter more fully defined.

I find that under suitable conditions part, or the whole of the circuit containing the source of direct current energy can be used in forming the above-mentioned shunt circuit to the converting device, so that the reinforcing of the energy of an already existing varying or alternating current, or the production of alternating current may take place in the circuit containing the source of direct current energy with or without the use of the whole or part of the above-mentioned shunt circuit. . . . .

In order to increase the energy of an already existing varying or alternating current, the converting device should be made to form part of the circuit in which the existing current is flowing. . . .

I find it an advantage, in some cases, to prevent direct current energy from flowing round the shunt circuit, and for this purpose I may employ a condenser, and also to prevent the varying or alternating currents from flowing round the circuit containing the source of direct current energy, and for this purpose I use a highly-inductive resistance. . . . .

Such a method and device will produce alternating currents or oscillations of high frequency and constant amplitude, which can be

used with advantage, in wireless telegraphy especially where it is required to tune the transmitter and receiver to syntony, as compared with present methods in which a series of groups of oscillations are used, the oscillations in each of the said groups, rapidly decreasing in amplitude. . . . .

When using as a converting device a conductor, such as the electric arc, which emits sound waves when the current through it varies, I find the pitch of the sounds emitted is determined by the frequency of the variations of the current flowing through it, and will thus give an audible indication of such frequency or change of frequency, which may be applied to practical purposes. A series of musical notes may be artificially produced in such case, by a control of the frequency of the varying current, which may be done by varying as by means of a keyboard the capacity or self-induction or both of the shunt circuit which I use in carrying out my invention.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. A method and means for the conversion of electrical energy obtained from a source of direct current into the energy of varying or alternating currents which are sympathetic, or of controllable frequency, consisting of utilizing a specific conductor connected to a source of direct current in such a way that the said specific conductor shall form part of the circuit in which the varying or alternating current energy is required, the aforesaid specific conductor being of such a character that the ratio of the change in the current passing through the said conductor to the corresponding change in the potential difference between the terminals of the said conductor is a negative quantity, substantially as hereinbefore described.

5. In a method for the conversion of electrical energy derived from a source of direct current into the energy of varying or alternating currents, in which the electric arc is used as the specific conductor or converting device, controlling the frequency of the varying or alternating current, as by means of a keyboard, for the production of a series of musical notes, substantially as described.

Dated this 29th day of August, 1901.

FELL & JAMES,
1 Queen Victoria Street, London, E.C.,
Agents for the Applicant.

EXTRACTS FROM THE AMENDED SPECIFICATION OF BR. PAT. NO. 15,599, A.D. 1903

(Amended in accordance with the decision of the Comptroller-General, dated the 11th day of June, 1917)

Date of Application, July 14, 1903
Complete Specification Left, April 13, 1904
Accepted, July 14, 1904

COMPLETE SPECIFICATION (AMENDED)

Improvements Relating to the Production of Alternating Electric Currents

I, Valdemar Poulsen, of 22 St. Blichersvej, in the City of Copenhagen and Kingdom of Denmark, Civil Engineer, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

As demonstrated by Duddell (British Patent No. 21,629, 1900), it is possible by suitable employment of self-induction, capacity, and an electric conductor of such a character, that the ratio of the change in the current passing through the said conductor to the corresponding change in the potential difference between the terminals of the said conductor, is a negative quantity, that is to say: the potential decreases, when the current increases, to produce an alternating current from a continuous current. In this way, only a proportionately low efficiency has hitherto been reached.

The present invention aims at increasing this efficiency by placing the conductor in question in the form of an electric arc in an atmosphere consisting of hydrogen or hydrogen compounds producing in a similar way alternating currents of greater useful effect, and, if desired, of a much higher frequency (200,000—1,000,000 or more), the conductor being at the same time arranged in a magnetic field, by which the effect is still more essentially increased. . .

On Fig. 1, *a* and *b* indicate the feed conducting wire for a continuous current, *d* a self-induction coil, *e* an electric arc, formed between two carbons, *l* the self-induction of the circuit of the alternating current and *k* a condenser. The number of alternations of the circuit of the alternating current is then found to be approximately

$$\frac{10^3}{2\pi} \qquad \frac{1}{\sqrt{LK}} \quad \text{per second}$$

where L is henry and K microfarad. On account of the self-induction coil *d*, alternating currents are prevented from streaming

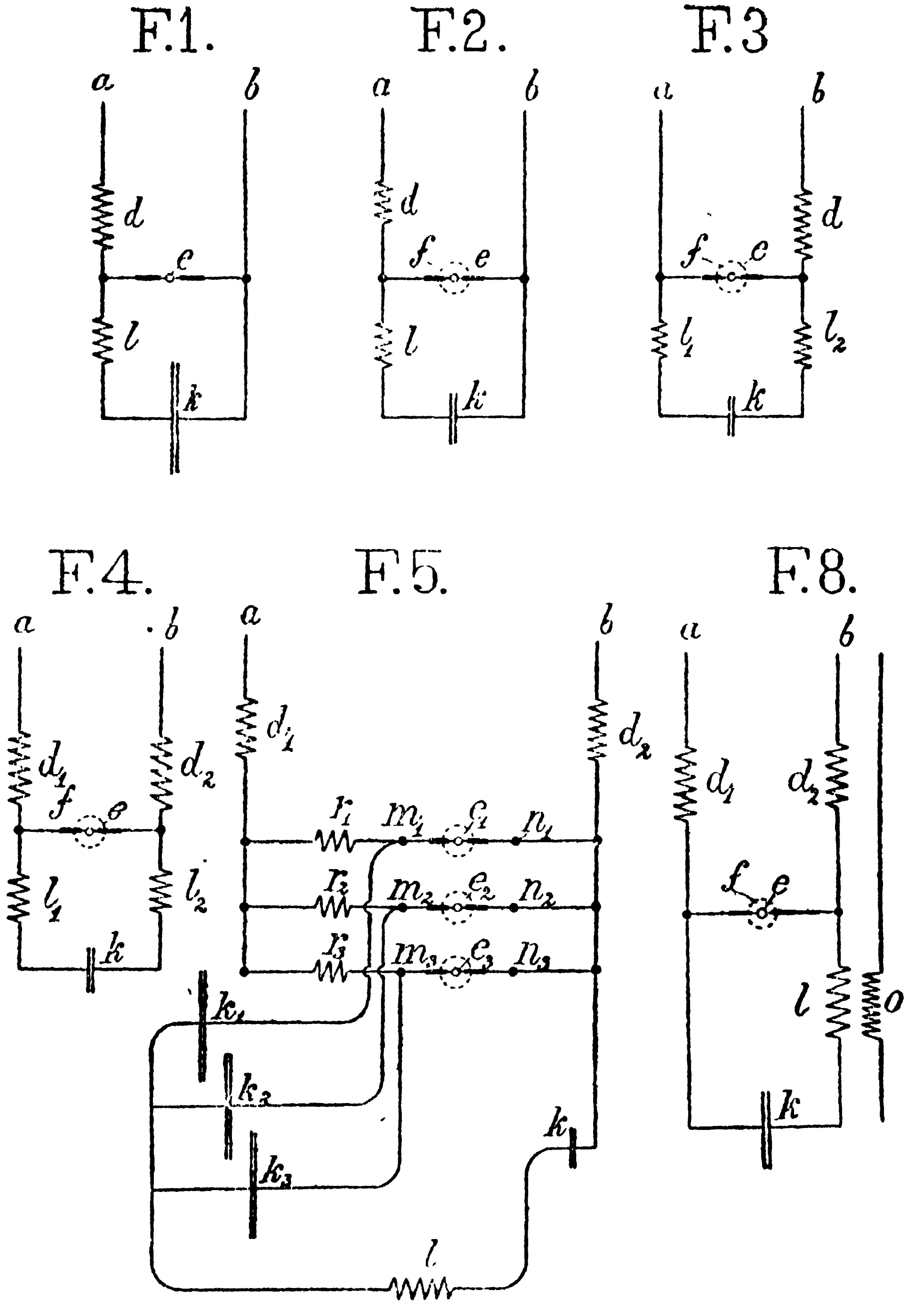
F.1.
F.2.
F.3
F.4.
F.5.
F.8.
a
b
d
e
f
l
k
d1
d2
l1
l2
r1
r2
r3
m1
m2
m3
e1
e2
e3
n1
n2
n3
k1
k2
k3
o

Fig. XX.

out in the feed conduction wires. As stated, the alternating currents, produced in this way, are rather limited, both as regards intensity and number of vibrations. However, by introducing the electric arc into an atmosphere of hydrogen or some other hydrogen compound, the efficiency, intensity and frequency can be increased considerably.

A simple method of carrying out the invention (the magnetic field mechanism not being shown) is shown in Fig. 2 the electric arc *e* being surrounded by an atmosphere *f* containing hydrogen. This can most simply be executed by arranging the electric arc and the neighbouring parts of the electrodes in a flame of illuminating gas near the opening for letting out the gas.

Fig. 3 shows the same device, but with two self-induction coils l_1 and l_2 placed one on each side of the electric arc in the alternating circuit.

The device shown in Fig. 4 has two self-induction coils d_1 and d_2 which prevent the alternating current from streaming out upon the conductors of the continuous current and are inserted one on each side of the electric arc.

When the intensity of the current exceeds a certain limit, the alternating currents will cease.

Fig. 5 shows a device, by which it is possible to transfer a considerable quantity of energy with same number of vibrations in the system of alternating currents, by means of a plurality of electric arcs placed in parallel. The letters *a b* d_1 and d_2 refer to like parts as in Fig. 4. . . . .

The substantial self-induction of the alternating system is here placed in *l* and the substantial resistance in the electric arcs e_1 e_2 and e_3.

The capacity of each of the condensers k_1 k_2 and k_3 is greater than the capacity of the condenser *k* and the capacities are mutually adjusted in such a manner, that the electric arcs e_1 e_2 and e_3 are approximately or completely syntonized.

As will be seen, the condensers k_1 k_2 and k_3 keep the electrodes m_1 m_2 and m_3 thus separated from each other that continuous current cannot pass from one electrode to the other. As the electrodes n_1 n_2 and n_2 have all the same potential, they may be replaced by a single electrode. . . . .

In this and similar ways as many electric arcs as desired may be joined in parallel and a syntonic addition of the alternating currents, produced by the electric arcs, can be obtained. Of course the alternating currents, produced by the electric arcs arranged in parallel can have different frequencies and the interference effect resulting therefrom, can be employed. . . . . . .

If, as shown in Fig. 8, the self-induction *l* forms the primary coil of a transformer, oil-insulated, an alternating current of higher or lower potential can be induced in the secondary coil of same. The secondary conductor *o* combined with the devices known in the art of wireless signalling, can be used for wireless telegraphy, and telephony, and on account of the continuance of the waves produced,

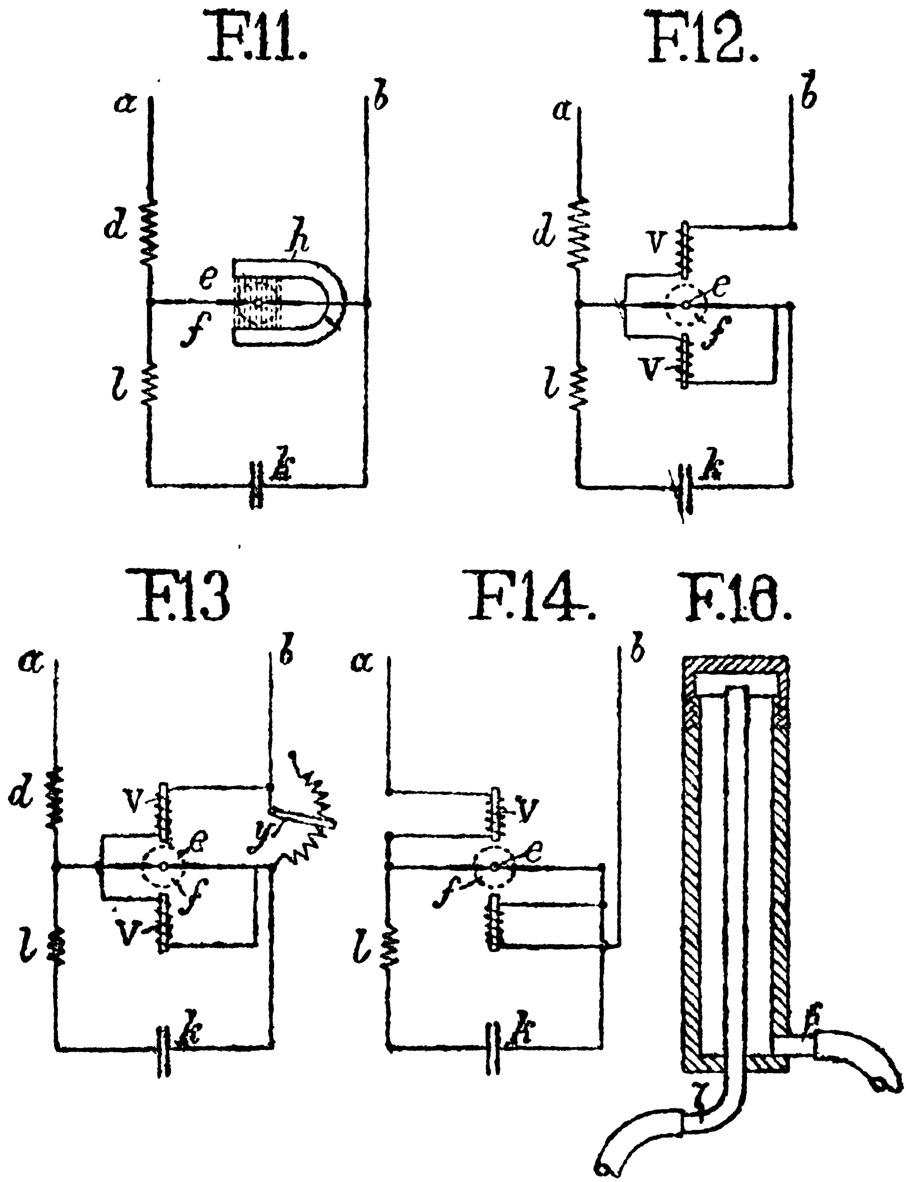

Fig. XXa.

being of determined length, the system is fit for syntonized telephony and telegraphy. . . . .

Wireless signalling and all the other phenomena mentioned can be carried out even without a real transformer, when sufficient difference of potential between the coatings of the condenser *k* is produced. . . . .

It is not necessary, that the feed-conductors *a* and *b* should conduct continuous current; an alternating current can also in the manner above described be transformed into an alternating current of some other frequency. . . . .

An essentially more useful effect is obtained by placing the arc in a magnetic field, the lines of force of which are perpendicular to the conductor, or have some other suitable position. The magnet can either be a permanent or an electro-magnet, and this latter can be energized from the same source of electricity as the electric arc.

It is specially suitable to produce the electric field by means of an electro-magnet (with or without iron-core), which is placed in series with the electric arc. The inductive resistances d_1 and d_2 can then form the coils of the electro-magnet. In some special cases the self-induction l, l_1 and l_2 may also serve for producing the magnetic field. . . . .

As illustrated in Fig. 12 the magnetic field is produced by means of a pair of electro-magnets *v v* the coils of which are traversed by the current which feeds the arc.

Fig. 13 shows a device only differing from the device shown in Fig. 12 in that only part of the feeding current is led through the magnet coils, the remainder of the current passing through a resistance, the amount of which can be varied by turning the switch arm *y*. The intensity of the electro-magnetic field can thereby be regulated as desired.

Fig. 14 shows a diagram in which the coils of the magnets *v v* are placed as self-induction coils in the feed-conductors of the electric arc, and act in the same manner as the self-induction coil *d* in the other diagrams described.

The manner in which the electric arc is placed in a hydrogenic atmosphere can be greatly varied. In addition to the gas-flame previously mentioned, alcohol vapour, ether vapour or the like can be used, which vapours probably by the influence of the electric arc, will be dissociated into hydrogen and carbon. The electric arc can also be placed in a reservoir, containing hydrogen or a gaseous hydrogen-compound. . . . The pressure in the reservoir may be higher or lower than the pressure of the atmosphere. . . .

Fig. 16 shows an electrode, which can be cooled off by leading a jet of water in through the tube 7 and out through the tube 6 or *vice versa.*

The employment of such a cooled-off copper electrode as anode and a carbon rod as cathode is very appropriate.

An inconvenient deposit of carbon may take place by the

employment of carburetted hydrogen as media, or when carbon is employed as material for the electrodes; or the electrodes may be worn out in an irregular manner. Therefore it would be preferable to make the electrodes mutually adjustable, so that the pole-area is continually changed. . . . .

The invention as herein described may obviously be modified and the parts arranged in various forms to suit special requirements without departing from the spirit of the invention.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. Method for producing alternating currents with a high frequency by means of an electric conductor in the form of an electric arc the quality of which is that the ratio between an alteration in the current passing through the conductor in question and the corresponding alteration in the potential difference between the terminals of the conductor is a negative quantity, connected with a source of electricity in such a manner, that the conductor in question forms a part of the circuit in which the varying or alternating currents are produced, characterized by the conductor being arranged in an atmosphere of hydrogen or hydrogen-compound, and in a magnetic field.

2. A modification of the method mentioned in Claim 1 characterized by the hydrogen containing atmosphere surrounding the conductor being submitted to a pressure higher than one atmosphere.

3. A modification of the method mentioned in Claim 1 characterized by the hydrogen containing atmosphere surrounding the conductor being submitted to a pressure lower than one atmosphere.

4. A modification of the method mentioned in Claim 1 characterized by the electrodes being cooled off in a suitable manner.

5. A modification of the method mentioned in Claim 1 characterized by a plurality of conductors, e_1 e_2 e_3 arranged in parallel with associated condensers k_1 k_2 k_3—in series with the self-induction l of the alternating circuit (Figs. 5 and 6).

6. A modification of the method mentioned in Claim 5 characterized by the electric arcs arranged in parallel having a common electrode.

7. A modification of the method mentioned in Claim 1 characterized by a plurality of conductors being arranged in series.

8. A modification of the method mentioned in Claims 1-7 characterized by the alternating currents being conducted to a branch conductor of the condenser k.

9. A modification of the method mentioned in Claim 1 characterized by the produced alternating currents of a high frequency, being employed in connection with apparatuses for wireless telegraphy and telephony and other wireless transmission of energy.

10. A modification of the method mentioned in Claims 1-7

characterized by the alternating currents being used for producing cathode-rays, Röntgen-rays, and the like.

11. A modification of the method mentioned in Claims 1-10 characterized by either one or more electrodes being arranged to rotate.

12. A modification of the methods mentioned in Claims 1-11 characterized by the magnetic field being produced by an electro-magnet, the coil of which is traversed by the current, which feeds the conductor.

13. A modification of the methods mentioned in Claims 1-11, characterized by the coils of the electro-magnets being used as self-induction coils in the feed conductors for the electric arc.

Dated this 13th day of April, 1904.

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